KEITHLEY

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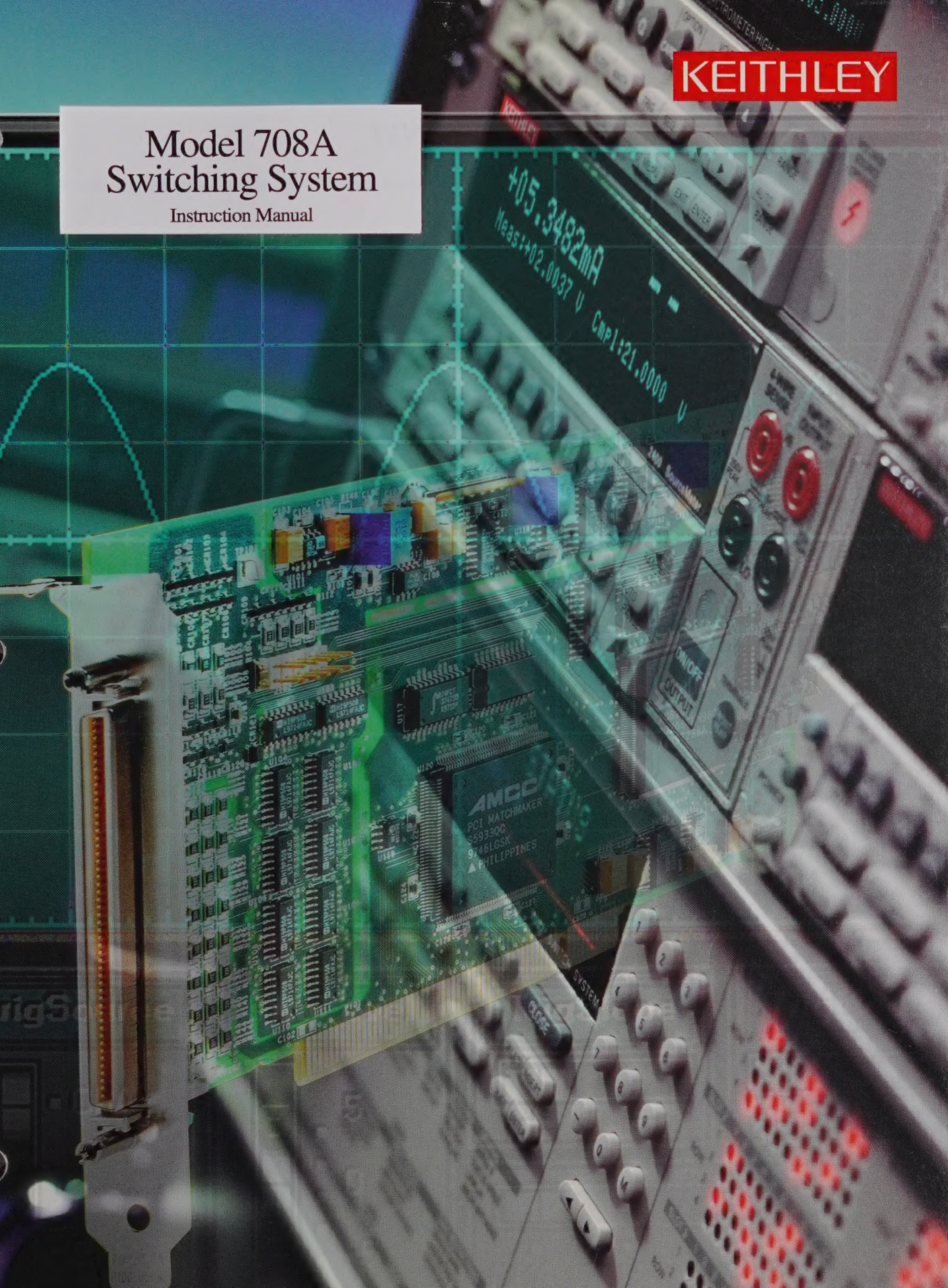
Model 708A Switching System

Instruction Manual



Model 708A Switching System

Instruction Manual

Contains Operating and Servicing Information

KEITHLEY

708A-901-01 / A

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Model 708A Switching System
Instruction Manual

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Manual Print History

The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

Revision A (Document Number 708A-901-01)..... September 1998

All Keithley product names are trademarks or registered trademarks of Keithley Instruments, Inc.
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Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read the operating information carefully before using the product.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, digital multimeter measuring circuits (e.g., Keithley Models 175A, 199, 2000, 2001, 2002, and 2010) are Installation Category II. All other instruments' signal terminals are Installation Category I and must not be connected to mains.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

708A Switching System

Overview

CAPACITY: One plug-in card per mainframe

EXPANSION CAPACITY: Daisy-chain expansion of up to four Slave units with one Master unit.

ANALOG BACKPLANES: Connections provided for user-supplied cable. Provides automatic row expansions between 7071, 7071-4, 7073, 7074, 7075, 7076 and 7077 cards in separate 708 mainframes.

DISPLAY: Crosspoint and IEEE-488 bus status.

MEMORY: Storage for 100 matrix setups, battery backup.

PROGRAMMED SETTLING TIME: 0 to 65 seconds in 1ms increments.

FRONT PANEL CONTROL: Crosspoint Control, Factory Default, Open, and Digital I/O.

TRIGGER SOURCES: External Trigger (TTL compatible, programmable edge, 600ns minimum pulse width); IEEE-488 bus (TALK, GET, "X"); manual.

STATUS OUTPUT: Matrix Ready (TTL compatible programmable high or low true); goes false when relays are switched, true at end of Programmed Settling Time.

MAKE BEFORE BREAK, BREAK BEFORE MAKE: Programmable by row.

LIGHT PEN OPTION: Controls crosspoints.

Execution Speed

MAXIMUM TRIGGER RATE: 200 setups per second (stepping through previously stored setups with make-before-break and break-before make disabled)

TRIGGER RESPONSE TIME: External trigger: <1ms. IEEE-488 GET: <1ms.

RESPONSE TO IEEE-488 COMMAND (to close a single relay, excluding relay settling time):

Standalone: <15ms.

Master and Four Slaves: <55ms.

Download Time (one setup): 50ms typical.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

GENERAL

CARD INSTALLATION: Configurable for front or rear installation.

DIGITAL I/O:

OUTPUTS:

Configuration: 16 open collector drivers with factory-installed 10kΩ pull-up resistors. Each driver has internal flyback diodes.

Pull-up Voltage: 5V @ 65mA internally supplied. External connection provided for user supplied voltage 40V max.

Maximum Sink Current: 600mA per channel. 2A max.

Output Protection: Each output protected from short circuits with supply voltages up to 25VDC.

Logic: Negative true.

Collector-Emitter Saturation Voltage: <200mV @ 100mA
<400mV @ 400mA
<600mV @ 600mA

INPUTS:

Configuration: 16 inputs with internal 10kΩ pull-up resistor.

Maximum Voltage Level: 42V pk.

Logic: Positive true logic.

REAR PANEL CONNECTORS:

Two BNC: External Trigger, Matrix Ready.

Two DB-25: Digital I/O.

Two 8-pin DIN: Master/Slave In, Master/Slave Out.

EMC: Conforms with European Union Directive 89/336/EEC EN 55011, EN 50082-1, EN 61000-3-3, FCC part 15 class B.

SAFETY: Conforms with European Union Directive 73/23/EEC EN 61010-1.

ENVIRONMENT:
Operating: 0 to 50°C, <80% relative humidity (0° to 35°C).
Storage: –25 to 65°C.

POWER: 100–240V AC, 50–60Hz, 110 VA maximum.

RELAY DRIVE: 5A.

DIMENSIONS: 90mm high × 433 mm wide × 570 mm deep (3.5 in × 17 in × 22.4 in).

Specifications are subject to change without notice.

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1 General Information

1.1 Introduction

This section contains general information about the Model 708A Switching System. The Model 708A is designed as a programmable switch for connecting signal paths in a matrix topology. It is for applications requiring a small-scale matrix (up to 96 crosspoints per mainframe and 480 crosspoints per master/slave configuration). Plug-in cards are available for general and special purpose switching applications.

1.2 Features

Key features of the Model 708A Switching System are:

- The switching system accepts one 7X7X switching card (front or rear panel installation).
- Digital I/O contained in the switching system (sixteen inputs and outputs with internal pull-up resistors).
- IEEE-488 bus or interactive programming.
- Storage of 100 sets of relay setups, which can be uploaded or downloaded through the IEEE-488 interface.
- An active front panel LED display shows the present relay status, a stored setup, or an editing scratchpad.
- High-speed triggering of stored setups.
- Make/break and break/make switching programmable matrix by rows. Operation is transparent and independent of the relay setup.
- Maximum matrix size of 8 rows by 60 columns (480 crosspoints on one IEEE-488 address with five units connected in a master/slave configuration).
- Sealed construction, low heat producing design eliminates vent holes, which is suitable for cleanrooms.
- An optional light pen is available for interactive control of relays and editing stored relay setups.

1.3 Warranty information

Warranty information is located at the front of this manual. Should your Model 708A require warranty service, contact your Keithley representative or an authorized repair facility in your area for further information.

1.4 Manual addenda

Any improvements or changes concerning the switching system or manual will be explained in an addendum. Be sure to note these changes and incorporate them into the manual before using or servicing the unit.

1.5 Safety symbols and terms

The following symbols and terms may be found on an instrument or used in this manual.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the instruction manual.

The symbol on an instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

1.6 Specifications

Model 708A specifications are located at the front of this manual. These specifications are exclusive of matrix card specifications, which are located in their appropriate instruction manual.

1.7 Unpacking and inspection

1.7.1 Inspection for damage

Upon receiving the Model 708A, carefully unpack the unit and inspect it for any obvious signs of physical damage. Report any damage to the shipping agent immediately. Save the original packing carton for possible future shipment. If installing a matrix card at this time, be sure to follow the additional handling precautions explained in the appropriate matrix card instruction manual.

1.7.2 Shipment contents

The following items are included with every Model 708A order:

- Model 708A Switching System.
- Model 708A Instruction Manual.
- Fixed rack mount kit (includes mounting hardware).
- Removable feet (for bench-top use — includes hardware).
- Additional accessories as ordered.

1.8 Repacking for shipment

Should it become necessary to return the Model 708A for repair, carefully pack the unit in its original packing carton or the equivalent, and perform the following:

- Call the Repair Department at 1-800-552-1115 for a Repair Authorization (RMA) number.
- Advise as to the warranty status of the switching system.
- Write ATTENTION REPAIR DEPARTMENT and the RMA number on the shipping label.
- Fill out and include the service form located at the back of this manual.

1.9 Optional accessories

The following accessories are available for the Model 708A.

Adapter and switching matrix cards

Model 7070 Universal Adapter Card — The Model 7070 card installs in the Model 708A and is jumper-selectable for use either as a backplane extender or a breadboard. It has quick-disconnect screw terminals and 10ft. ribbon cables.

Model 7071 General Purpose Matrix Card — The Model 7071 card has 8 rows by 12 columns of three-pole Form A switching for general purpose applications. It has mass terminated connectors in addition to quick-disconnect screw terminals.

Model 7071-4 Dual 4 × 12 General Purpose Matrix Card — The Model 7071-4 card has two banks of four signal paths of three-pole switching. Row and column connections to the matrix are through 38-pin mass terminated connectors.

Model 7072 Semiconductor Matrix Card — The Model 7072 card has 2 rows by 12 columns of two-pole Form A for low current switching, 4 rows by 12 columns of two-pole Form A for general purpose switching, and 2 rows by 12 columns of one-pole Form A for C-V switching. It has three-lug triaxial connectors.

Model 7072-HV High Voltage Matrix Card — The Model 7072-HV switches low level, high voltage, and high impedance signals for semiconductor parametric tests. It has two low current paths, four general purpose paths, and two C-V paths. Connections to the matrix are through triax connectors.

Model 7073 Coaxial Matrix Card — The Model 7073 card has 8 rows by 12 columns of one-pole Form A switching (up to 30MHz) for applications with single-ended instruments. It has BNC connectors.

Model 7074-D Eight 1 × 12 General Purpose Multiplexer Card — This card has eight banks of one signal path of three-pole switching. Bank connections are through four 75-pin mass terminated connectors; row connections are through one 38-pin mass terminated connector.

Model 7075 Eight 1 × 12 Two-Pole Multiplexer Card — The Model 7075 is a general purpose multiplex switching card that consists of eight banks of independent 1 × 12 multiplexer switching. Eight 25-pin D connectors are provided for bank connections and one for row connections.

Model 7076 Dual 4 × 12 Two-Pole Matrix Card — The Model 7076 is a general purpose matrix switching card that consists of two independent 4 × 12 switching matrices. Each matrix has two switched circuits (HI and GUARD). The four row signal paths are connected through jumpers to the general purpose analog backplane in the Model 708A. Connections to the matrix are through standard 25-pin D connectors for mass termination.

Model 7077 8 × 12 Isolated Coaxial Matrix Card — The Model 7077 has 8 rows by 12 columns of two-pole Form A switching for general purpose applications. It has BNC connectors.

Model 7172 Low Current Matrix Card — The Model 7172 is for semiconductor I-V and C-V measurements. It is configured in an 8 × 12 matrix of two-pole switching with triax connectors. An on-board electrometer measures offset current.

Model 7173-50 4 × 12 High Frequency Matrix Card — This card combines high frequency performance with excellent DC switching characteristics. It provides 200MHz bandwidth in a 4×12 matrix configuration. It has BNC connectors.

Model 7174 8 × 12 Low Current Matrix Card — The Model 7174 is designed for high performance switching of I-V and C-V signals. It has triax connectors.

Digital I/O cables

Model 7075-MTC Standard Cable — Standard 3m (10ft) cable assembly terminated with 25-pin D-sub plugs on both ends.

CS-400 Cable — 25-pin D-sub plug that will mate to the receptacles of the card. Solder-cup connections simplify the building of custom cables.

CS-401 Cable — 25-contact D-sub receptacle that will mate to the cables terminated with a 25-pin D-sub plug.

CS-590 Cable — Plastic backshell housing for CS-400.

Note: The following two cables are available from 3M Corporation.

8225-7000 (3M) Cable — 25-pin D-sub plug for customized ribbon cable assemblies.

3357-9225 (3M) — Junction shell for 3M 8225-7000 D-sub plug.

Miscellaneous cables and accessories

Model 7007-1 Shielded IEEE-488 Cables — The Model 7007-1 connects the Model 708A to the IEEE-488 bus using shielded cables to reduce electromagnetic interference (EMI). The Model 7007-1 is 1m (3.3ft) long and has an EMI shielded IEEE-488 connector at each end. This cable is also available in a 2m (6.6ft) length (Model 7007-2).

Model 7051-2 BNC to BNC Cables — The Model 7051-2 makes connections to external trigger and matrix ready on the Model 708A rear panel. The Model 7051-2 is a 50Ω BNC to BNC cable (RG-58C), which is 0.6m (2ft) long. This cable is also available in a 1.5m (5ft) length (Model 7051-5).

Model 7078-PEN Programming Light Pen — The Model 7078-PEN connects to the Model 708A front panel. It is used to toggle the states of the LEDs that display crosspoints and digital I/O. A pen holder is included.

Model 8501-1 and 8501-2 Trigger Link Cables — The Model 8501-1 and 8501-2 contain an 8-pin male DIN connector. The Model 8501-1 is 1m (3.3ft) in length, and the Model 8501-2 is 2m (6.6ft) in length. Multiple cables are used for connecting Model 708A units in a master/slave configuration through the rear panel master/slave connectors.

Note: The following backplane expansion components are available from 3M Corporation.

Backplane expansion (20-pin cable components)

3365/20 (3M) — 28 AWG ribbon cable rated at >200VDC.

3461-001 (3M) — 0.1 inch card-edge connector with a current rating of 1A > 200VDC (one connector required for each Model 708A).

3448-54 (3M) — Strain relief.

Backplane expansion (50-pin cable components)

3365/50 (3M) — 28 AWG ribbon cable rated at >200VDC.

3415-0001 (3M) — 0.1 inch card-edge connector with a current rating of 1A > 200VDC (one connector required for each Model 708A).

3448-54 (3M) — Strain relief.

2

Card Installation

2.1 Introduction

WARNING

The procedures in this section are intended for use by qualified service personnel only. Do not perform these procedures unless qualified to do so. Failure to recognize and observe normal safety precautions could result in personal injury or death.

Installation procedures are described in this section.

2.2 Changing card installation access

The configuration chosen for each Model 708A Switching System (front or rear) can simplify connections and shorten the wiring required for each installation. As shipped from the factory, the unit is configured for rear panel card installation. With the Model 708A Switching System configured for front panel card installation, the card and connections can be accessed from the front of the rack. Use the following procedure to change the Model 708A configuration for front or rear panel card installation.

WARNING

Turn off power from all instrumentation (including the Model 708A Switching System) and disconnect all power line cords. Make sure all power is removed and stored energy in external circuitry is discharged prior to changing card installation configuration.

CAUTION

To prevent contamination, handle matrix cards and backplane using lint-free gloves. If contamination occurs, clean according to the card's instruction manual.

1. Remove the card, slot cover, and analog backplane from the Model 708A Switching System by loosening the spring-loaded mounting screws (see Figure 2-1).
2. Install analog backplane on the Model 708A Switching System panel. Make sure the analog backplane connector (P1015) is inserted completely into its mating connector. The mating connector will be J1015A for front panel card installation and J1015B for rear panel card installation.
   - Front panel card installation — Install the analog backplane on the rear panel of the unit.
   - Rear panel card installation — Install the analog backplane on the front panel of the unit.
3. Secure and ground by tightening the spring-loaded mounting screws.

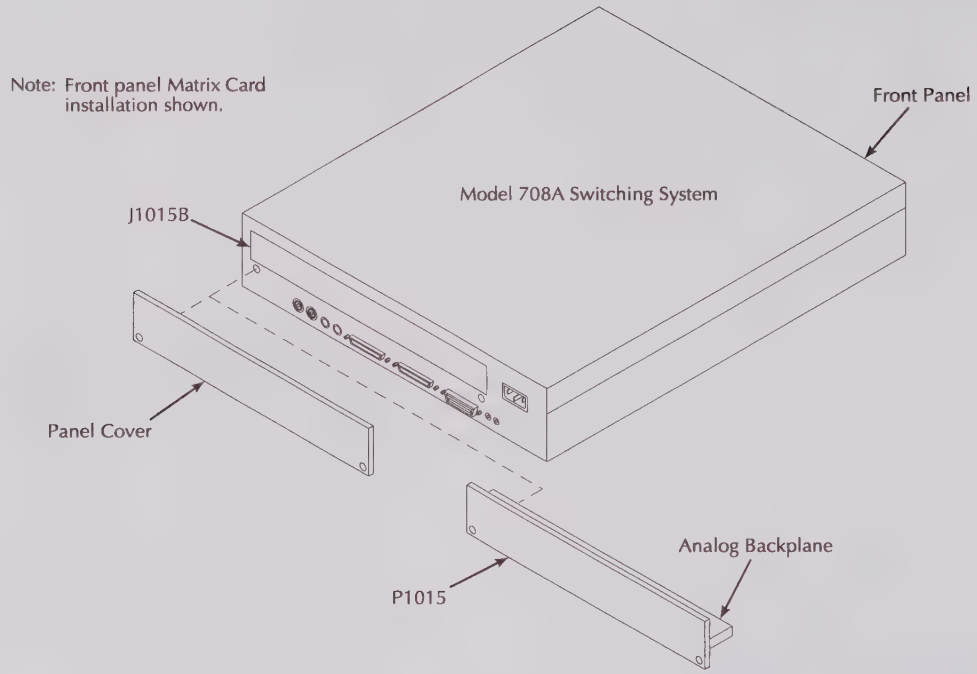


Figure 2-1
Model 708A switching system – changing switch card installation

2.3 Card installation/removal

Before operating the Model 708A in a test environment, install a card in the switching system. Although cards are not needed to program setups for master/slave configurations, make sure the loop connections are present.

Card installation

Using Figure 2-2 as a guide, install a card in the Model 708A Switching System as follows. Specific card instructions can be found in the appropriate card's manual.

WARNING

Before installing or removing cards or making card connections, turn off mainframe power and disconnect the line cord. Also, make sure no power is applied from the user's circuit.

CAUTION

Do not touch the card surfaces, connectors, or components to avoid contamination that could degrade card performance.

NOTE

Some cards have connectors that are inaccessible once the card is fully inserted into the switching system (e.g., the quick disconnect terminal blocks on Model 7071 cards). In these cases, connect wires to the row and column terminal blocks before seating the card fully in the backplane connectors.

1. Remove the slot cover (if installed).
2. Using lint-free gloves, install the card.

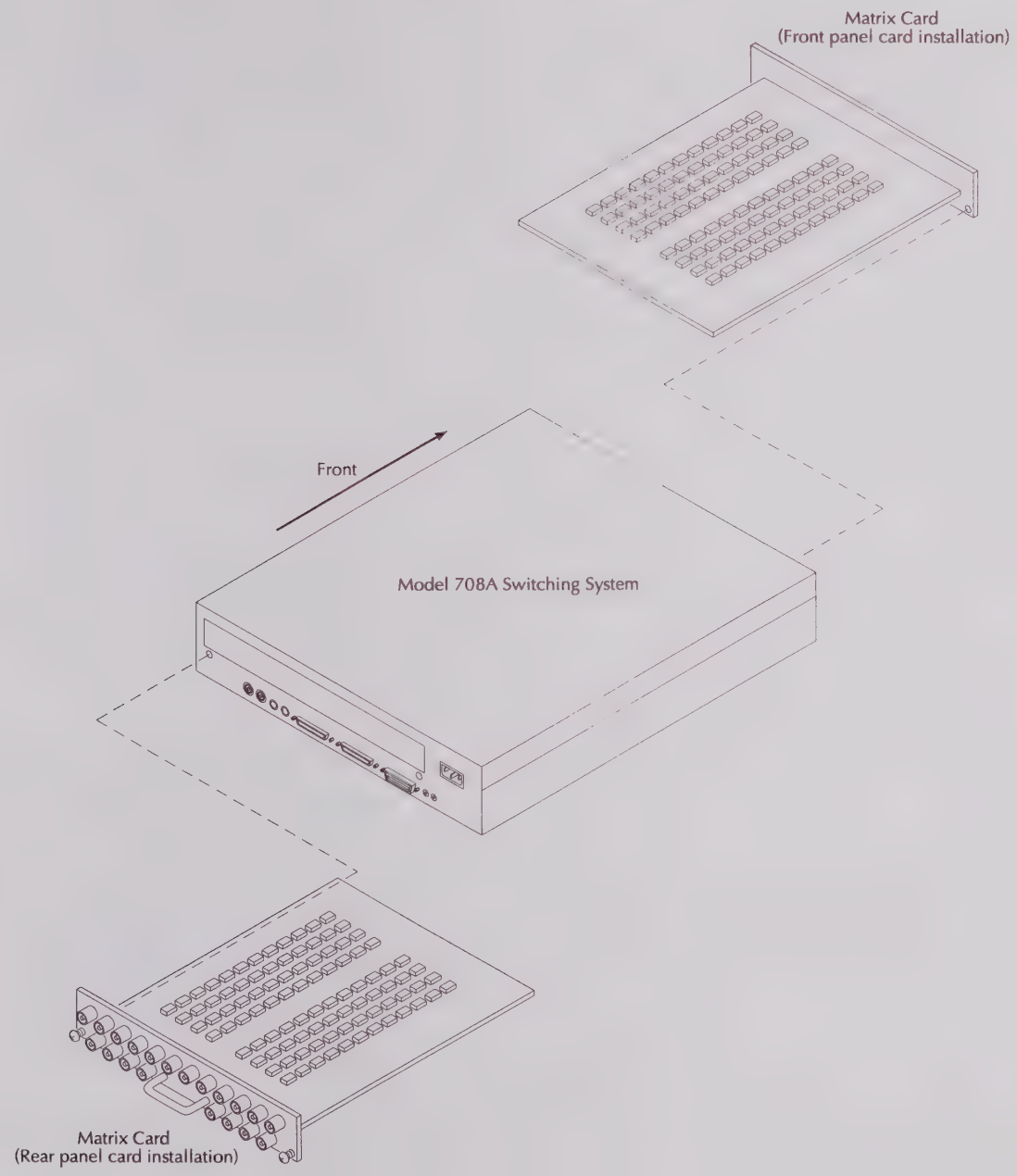


Figure 2-2
Matrix card installation

CAUTION

Properly support the card until it is fully seated in the Model 708A's analog backplane. If the card is not supported until it is fully seated, it may be damaged by its own weight.

3. Pick up the card with both hands (one hand grasping the handle and the other hand supporting the weight of the card).
4. Align the card in the Model 708A. Make sure the edges of the card slide into the card edge guides and the component side of the card is facing up.
5. Slide the card into the Model 708A. Make sure the card is fully seated in the analog backplane.
6. Tighten the spring-loaded mounting screws with a Philips screwdriver.

WARNING

The mounting screws must be secured to ensure a proper chassis ground connection between the card and the Model 708A Switching System. Failure to properly secure this ground connection may result in personal injury or death due to electric shock.

Card removal

Using Figure 2-2 as a guide, remove a card from the Model 708A Switching System as follows. Specific card instructions can be found in the appropriate card's manual.

WARNING

Before installing or removing cards or making card connections, turn off mainframe power and disconnect the line cord. Also, make sure no power is applied from the user's circuit.

CAUTION

Do not touch the card surfaces, connectors, or components to avoid contamination that could degrade card performance.

NOTE

Some cards have connectors that are inaccessible once the card is fully inserted into the switching system (e.g., the quick disconnect terminal blocks on Model 7071 cards). In these cases, remove wires from the row and column terminal blocks before fully removing the card from the backplane connectors.

1. Using lint-free gloves, remove the card.
   - Loosen the spring-loaded mounting screws.
   - Pull out the card by its handle (one hand grasping the handle and the other hand supporting weight of card).

CAUTION

Properly support the card while removing it from the mainframe. An unsupported card may be damaged by its own weight. Store cards properly. Refer to the appropriate card manual's handling and cleaning precautions for specific instructions.

2. Install the slot cover (or other card as applicable).

3

Getting Started

3.1 Introduction

This section contains information on operating the Model 708A. It includes a brief description of operating controls and connections. Once you are familiar with the material presented here, refer to Section 4 for more detailed information.

3.2 Front panel familiarization

An overview of the Model 708A front panel operation is given in the following paragraphs. The front panel switches are shown in Figure 3-1. The front panel of the Model 708A accepts plug-in matrix cards when configured for front panel matrix card installation (refer to paragraph 2.2). When configured for rear panel matrix card installation, the front panel contains the analog backplane. Figure 3-2 illustrates setup data transfers within the Model 708A.

All front panel keys except POWER are momentary-contact membrane switches. The COPY key has an LED indicating the copy function. When the LED is lit, any changes made to the crosspoint display will be immediately copied to the relays.

CAUTION

When changing setups, use caution when the COPY key is enabled (the corresponding LED will be lit). Accidental connections may be copied to the relays causing instrument damage.

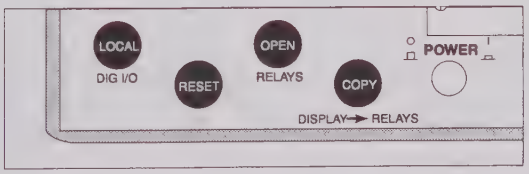


Figure 3-1
Model 708A front panel switches

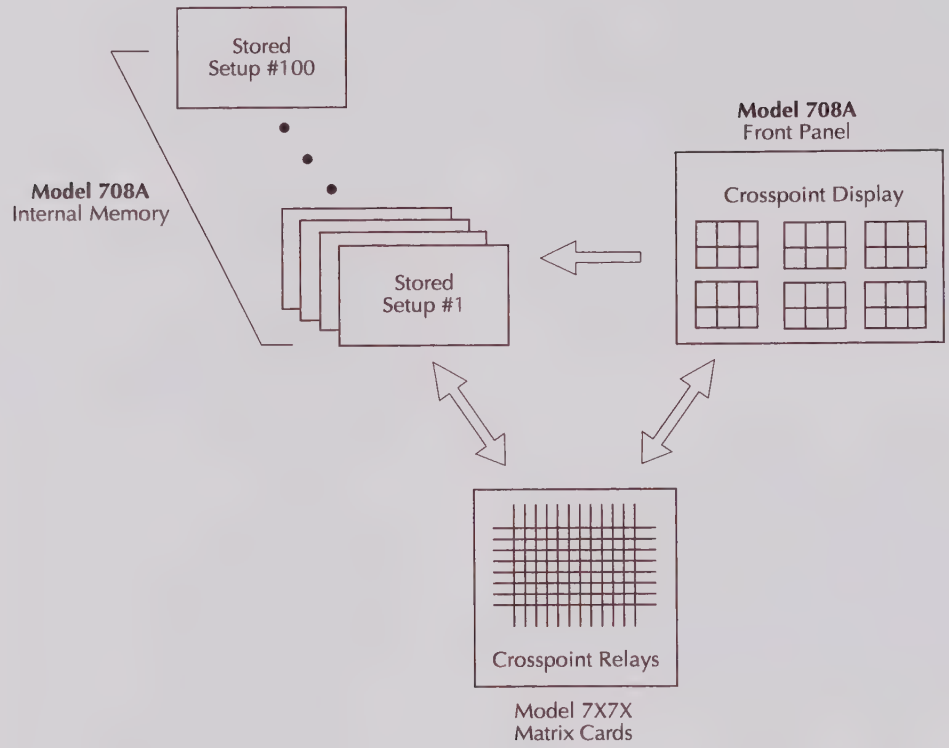


Figure 3-2
Setup data transfers

3.2.1 LED matrix

Use the LED matrix to monitor (or change using the optional light pen) the CROSSPOINT (relay) status or DIGITAL I/O status (see Figure 3-3). The CROSSPOINT display mode is the default mode for the Model 708A.

CROSSPOINT — Shows crosspoint status for the present relay setup, a stored relay setup, or an edited relay setup. The LED matrix (8 rows by 12 columns) shows on/off states of the card setup. States can be changed by the IEEE bus or the optional light pen. Crosspoint configurations can be stored in memory or sent to relays. A closed relay is indicated by a lit LED.

DIG I/O — When the Model 708A is placed in digital I/O display mode, the LED matrix shows the present digital IN/OUT status. The digital IN LEDs are located in rows A-H, columns 1-2. The digital OUT LEDs are located in rows A-H, columns 11-12. States can be changed by the IEEE bus or the optional light pen.

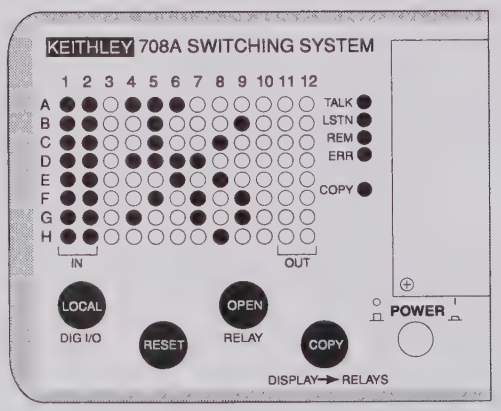


Figure 3-3
Digital I/O status display

IN — Displays the present status of the digital input on the LED matrix. Logic high is indicated by a lit LED. The digital input display status is continuously updated. Table 3-1 lists digital input display formats.

Table 3-1
Digital input display formats

Row/Column	Input #	Row/Column	Input #
A1	1	A2	9
B1	2	B2	10
C1	3	C2	11
D1	4	D2	12
E1	5	E2	13
F1	6	F2	14
G1	7	G2	15
H1	8	H2	16

OUT — Displays the present status of the digital output on the LED matrix. The output can be changed by clicking the light pen on the appropriate LED. Output high is indicated by a lit LED. Output low is indicated by an extinguished LED. The digital output display status is updated when the output is changed. Table 3-2 lists digital output display formats.

Table 3-2
Digital output display formats

Row/Column	Output #	Row/Column	Output #
A11	1	A12	9
B11	2	B12	10
C11	3	C12	11
D11	4	D12	12
E11	5	E12	13
F11	6	F12	14
G11	7	G12	15
H11	8	H12	16

3.2.2 Light pen connection

LIGHT PEN — An optional input device for toggling the on/off state of the crosspoint display LEDs and digital I/O LEDs. One light pen is used to control the LEDs of up to five Model 708A mainframes. Refer to Figure 3-1 for the location of the light pen connection. Refer to paragraph 4.4.4 for light pen operating information.

3.2.3 LED indicators

IEEE-488 Status Indicators

TALK, LSTN, REM — These three LED indicators apply to instrument operation over the IEEE-488 bus. The TALK and LSTN indicators show when the unit has been addressed to talk or listen. REM turns on to show when the unit is in the IEEE-488 remote state. See Section 4 for detailed information about operation over the bus.

Other Status Indicators

ERR — This LED lights when an error condition is flagged. The error condition is flagged in the serial poll byte when any bits in the Error Status Word are set. Refer to paragraph 5.9.20 for information on sending the Error Status Word (command U1).

COPY — When this LED is lit, any change to the crosspoint display is immediately sent to the relays. Refer to paragraph 3.2.4 for information on toggling the COPY LED.

3.2.4 Switches/connections

POWER — The power switch turns the unit on or off. The unit is on when the POWER pushbutton is in (depressed) and off when the POWER pushbutton is out.

CAUTION

The position of the POWER pushbutton indicates the power status of the Model 708A Switching System. The status of the crosspoint display and the other LEDs are not indications of power being applied to the Model 708A.

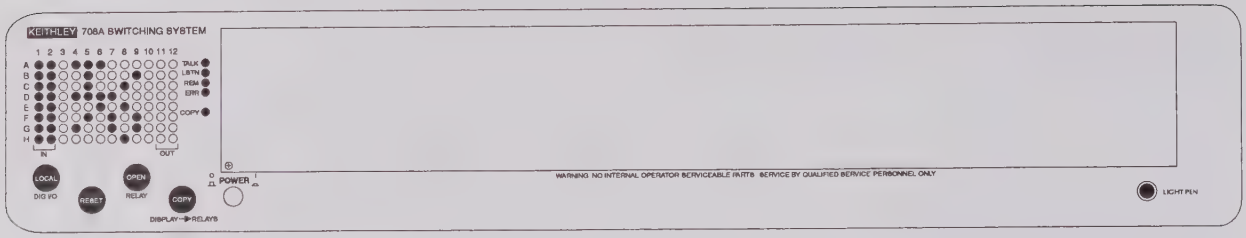


Figure 3-4
Front panel

LOCAL and DIG I/O — This key places the Model 708A in local (while in remote) or in digital I/O mode (while in local). While in digital I/O mode, I/O status will appear on the LED matrix (see Figure 3-3).

LOCAL — With the Model 708A in remote, pressing LOCAL returns the switching system to local mode (REMOTE off). While in local, operation of all front panel controls are active unless the Model 708A is in LLO (local lockout). For more information about local lockout, refer to paragraph 5.8.4.

DIG I/O — With the Model 708A in local, press this key to select digital I/O display mode (see Figure 3-3). Press this key a second time to return to local mode from digital I/O display mode. Refer to paragraph 3.2.1 for information on digital I/O display format.

RESET — Performs the same functions as cycling power (all relays are opened, triggers are disabled, RELAY STEP to 000, MEMORY STEP to 001, etc.) with the exception of power-up self-checking and master/slave loop initialization.

OPEN RELAYS — Turns off (opens) all present crosspoint LEDs (if not in digital I/O display mode). COPY must be enabled to open relays automatically.

COPY DISPLAY-RELAYS — Enables/disables automatic copying of the displayed crosspoint configuration to the relays. This causes any change to the crosspoint display to be applied immediately to the relays. This pushbutton also toggles the COPY LED (see paragraph 3.2.3) on and off.

3.3 Rear panel familiarization

The following paragraphs contain an overview of the Model 708A Switching System rear panel (see Figure 3-5). In addition to the various connectors, IEEE-488 address selection switches are located on the rear panel. Master/slave configuration and IEEE-488 (GPIB) addresses are set using these rotary selection switches. The rear panel of the Model 708A accepts plug-in cards when configured for rear panel card installation (see paragraph 2.2). When not configured for rear panel card installation, the rear panel contains the analog backplane.

Figure 3-5
Model 708A rear panel

EXT TRIGGER INPUT — A BNC jack for applying a trigger pulse to change to the next relay setup, if triggers are enabled and TRIG ON EXT is selected as the source. Pulses must be TTL-compatible, negative- or positive-going (programmable edge), with a duration greater than 600ns. Refer to the external trigger device-dependent command (DDC) in paragraph 5.9.2.

MATRIX READY OUTPUT — A BNC jack providing a TTL-compatible, high- or low-true level. It goes false when relays are switched and goes true after the sum of the relay settling time and the programmed settling time. Refer to the matrix ready device-dependent command (DDC) in paragraph 5.9.3.

MASTER/SLAVE OUT — An 8-pin DIN connector for connecting a cable to the next switching system in a master/slave daisy-chain configuration.

MASTER/SLAVE IN — An 8-pin DIN connector for connecting a cable from the previous switching system in a master/slave daisy-chain configuration.

DIGITAL I/O — Two DB-25 connectors.

Input — Sixteen inputs with internal pull-up resistors provide level shifting for direct micro-switch monitoring. Maximum voltage is 42V (peak).

Output — Sixteen open collector drivers with factory-installed 10kΩ pull-up resistors. Each driver has internal flyback diodes. Pull-up voltage is 5V at 65mA maximum. External connections are provided for user supplied voltage (40V maximum). Maximum sink current is 600mA per channel. Output short-circuit protection is provided up to 25VDC.

Refer to paragraph 4.6.1 for more information on the digital I/O ports.

IEEE-488 INTERFACE — This connector interfaces the Model 708A to the IEEE-488 bus. Refer to paragraph 4.6.5 for more information on the IEEE-488 interface port.

IEEE-488 ADDRESS SWITCHES — Two rotary switches set GPIB (IEEE-488) addresses and also designate master/slave units. From the factory, these switches are set to a GPIB address of 18. Valid switch settings are shown in Table 3-3. Refer to paragraph 4.6.5 for more information on the IEEE-488 interface port.

Table 3-3
IEEE-488 address switches

System type	Switch settings
Stand-alone unit	0 to 30
Slave of a master/slave system	0 to 30
Master of a master/slave system	31 to 60

AC RECEPTACLE — Power is applied through the supplied power cord to the three-terminal AC receptacle.

3.4 Card connections

3.4.1 Overview — matrix design considerations

Card connections provide connection terminals between the instruments and the DUTs. For each matrix card designed for the Model 708A, the rows can be lengthened by adding columns from other cards of the same model number through the analog backplane buses or with user-installed jumpers, depending on the card model. To manufacture a cable for analog backplane bus expansion, refer to paragraph 3.5.7. Rows are expanded across mainframe boundaries, either in a master/slave or stand-alone/stand-alone configuration. In a master/slave configuration of up to five switching systems, the rows are extended to 60 columns maximum. Paragraph 3.5 describes master/slave expansion.

The Model 708A Switching System is designed to be used with the cards listed in Table 3-4.

3.4.2 Connections — instruments to rows

If your application requires few instruments and many DUTs, connect the instruments to rows (up to eight) and the DUTs to columns (12 columns per matrix card/switching matrix, up to 60 columns with five matrix cards/switching matrices as stand-alone units or in a master/slave configuration). This connection scheme is optimum because the row-column path has only one crosspoint as shown in Figure 3-6. Expansion of rows leads to a long, narrow matrix containing one crosspoint as shown in Figure 3-7.

Table 3-4
Matrix and multiplexer cards

Card family	Model	Form
Universal	7070	96 Open Collector Drivers
General purpose	7071	8 x 12 Matrix
	7071-4	Dual 4 x 12 Matrix Card
	7074-D	Eight 1 x 12 Multiplexer Card
	7074-M	Eight 1 x 12 Multiplexer Card
	7075	Eight 1 x 12 Multiplexer Card
	7076	Dual 4 x 12 Matrix Card
Semiconductor	7072	8 x 12 Matrix Card
	7072-HV	8 x 12 Matrix Card
	7172	8 x 12 Matrix Card
	7174	8 x 12 Matrix Card
Coaxial	7073	8 x 12 Matrix Card
	7077	8 x 12 Matrix Card
	7173-50	4 x 12 Matrix Card

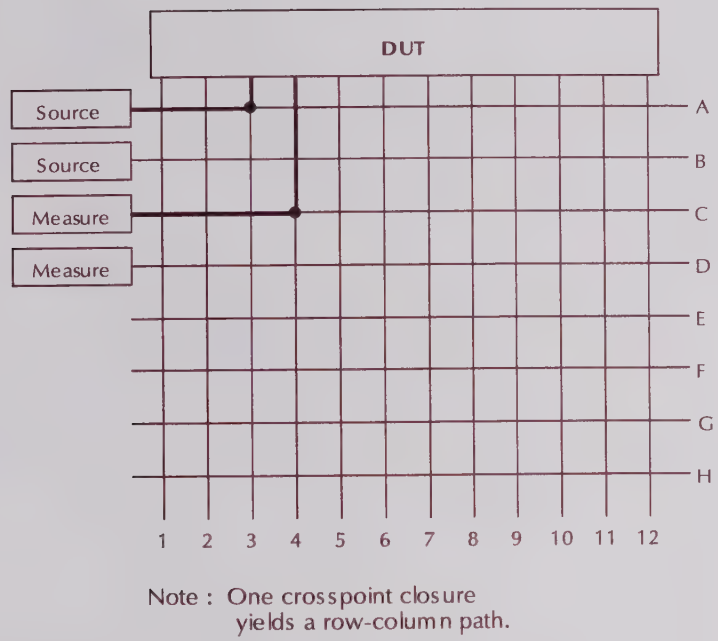


Figure 3-6
Connecting instruments to rows – single switching system

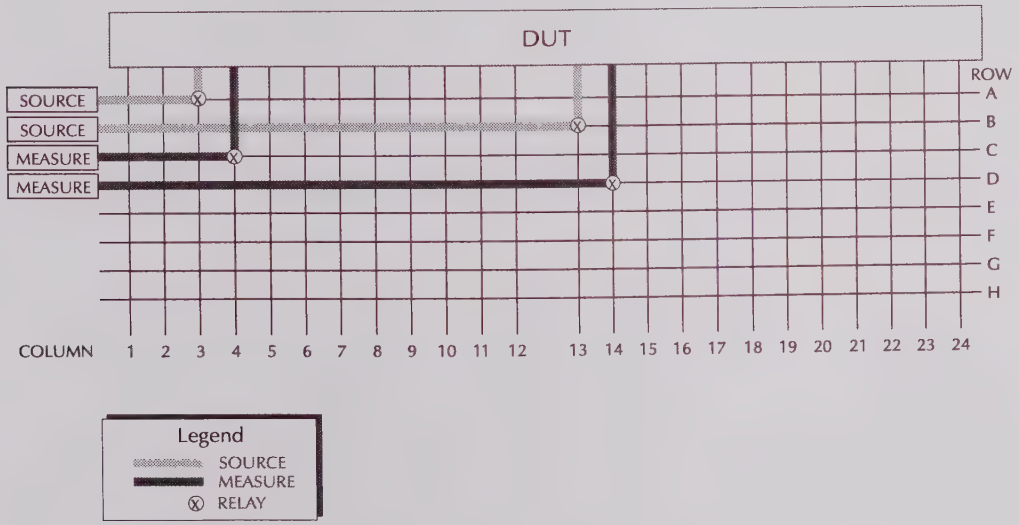


Figure 3-7
Connecting instruments to rows – multiple (two) switching systems

3.4.3 Connections — instruments to columns

An alternate connection scheme of the long, narrow matrix has all connections on the columns, both instruments and DUTs. This type of connection scheme is usually used in an expanded switching matrix (refer to paragraph 3.5) when the series of tests requires a large number of instruments and DUTs, with only a few signals for each test. As shown in Figure 3-8, with two cards, two crosspoint relays must be closed to complete a path from column-column (a safety benefit when sourcing). Multiple crosspoint paths, when compared with single crosspoint paths, have additional path resistance and contact potential.

Crosspoint programming becomes more complex with column-column paths because of the number of possible paths for large matrices and the choice of rows to complete the path (refer to Table 3-5).

Table 3-5
Row-column and column-column paths

	Crosspoints per path[1]	Possible paths for 8 rows × 12 columns	Possible paths for 8 rows × 60 columns
Row-column	1	96	480
Column-column[2]	2	66	1830

Notes:
1. The crosspoints per path do not account for any isolator relays present on a card.
2. Each column-column path can be made through one of eight rows (e.g., column 1 can be connected to column 2 by any of the following: closing A1 and A2, B1 and B2, C1 and C2, etc.).

The row completion choice for column-column paths on multiple application cards follows the recommendations given previously for row-column paths. With a Model 7072 card, close a crosspoint relay in row A or B for low current applications, row C, D, E, or F for general purpose switching, and row F or G for C-V switching.

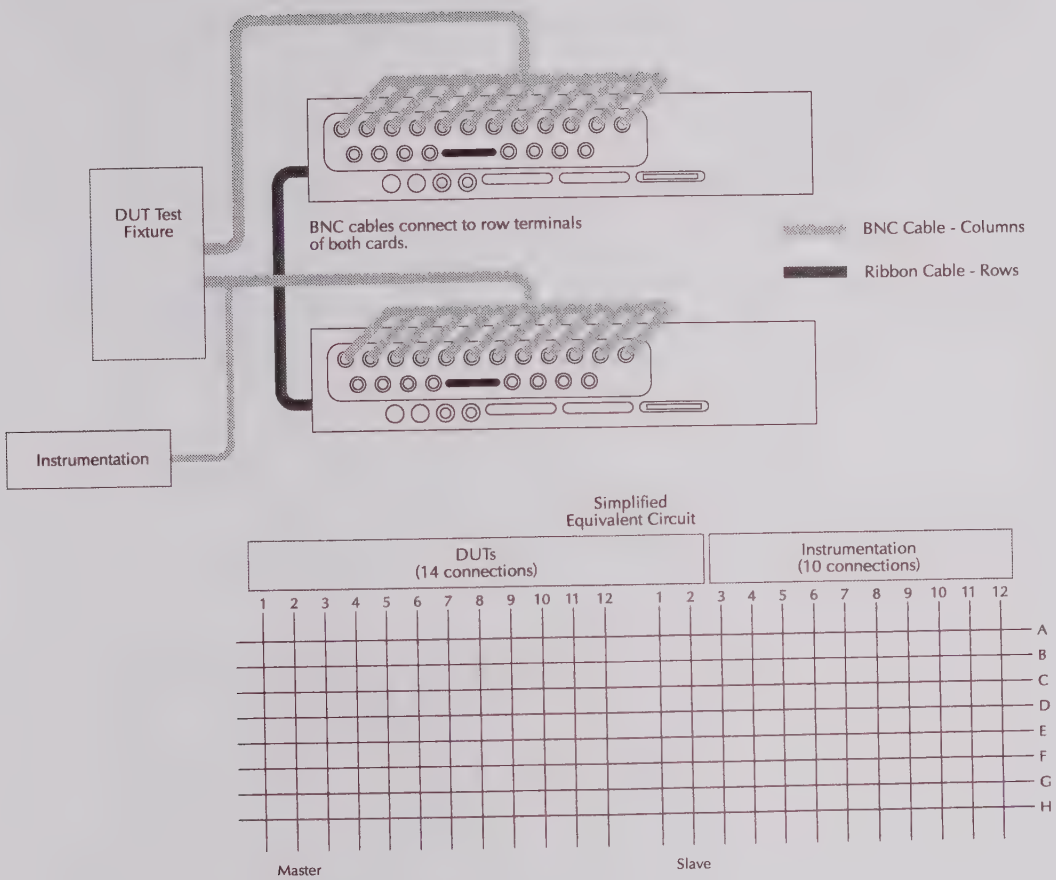
3.4.4 Connections — partial matrix expansion

External expansion of the cards can also be used to implement a partial matrix. As shown in Figure 3-9 (Model 7071 cards), a column connection is made between unit 3 and unit 4. With the example connections shown, three crosspoints must be closed to source (increasing the safety factor), but only one crosspoint closure is needed to measure (recommended for sensitive instruments).

3.4.5 Multiple application cards

Selecting the correct row connections for instruments is important with cards designed for multiple applications. Using the Model 7072 as an example, the recommended connections are:

- Rows A and B (low current) — Picoammeters, electrometers.
- Rows C through F (general purpose) — DMMs, sources.
- Rows G and H (C-V characteristics) — C-V analyzers.



Note: BNC matrix cards shown. Other card connections similar.

Figure 3-8
Connecting instruments to columns – multiple (two) switching systems

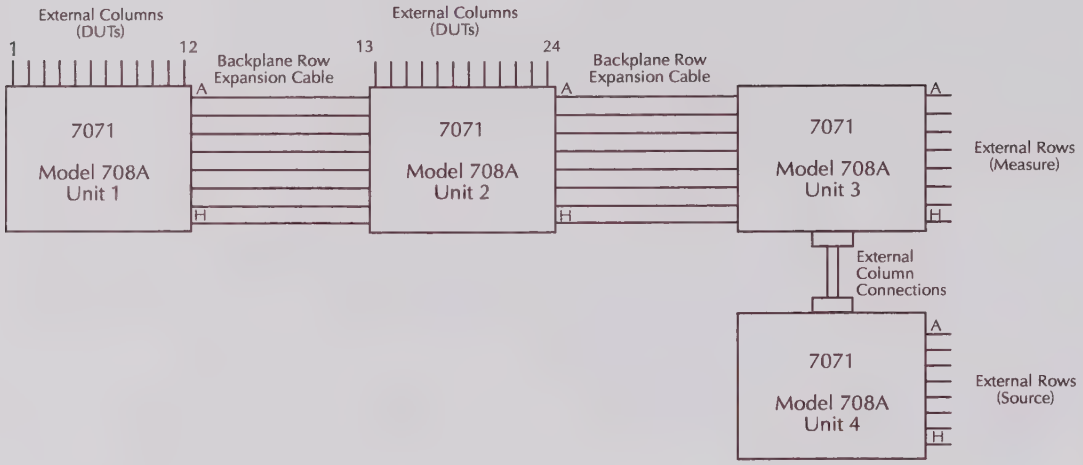


Figure 3-9
Partial matrix expansion example

3.5 Expanding matrix size

3.5.1 Overview — multiple matrix expansion

An 8 × 12 matrix card of the Model 708A Switching System is a building block for larger matrices. Matrix expansion is accomplished by the following two methods.

Backplane row expansion — The Model 708A backplane automatically extends rows from other like cards. Refer to Table 3-6 for a list of matrix cards supported by this feature. To enable automatic backplane expansion, one of two special cables must be constructed (refer to paragraph 3.5.7). Two types of backplane expansion are supported: analog expansion and analog expansion with control (master/slave). Refer to Figure 3-10. Analog backplane row expansion is discussed in paragraph 3.5.2. To expand using analog expansion with control (master/slave), first expand using analog backplane row expansion (paragraph 3.5.2), and then complete using control expansion (paragraph 3.5.4).

External (to backplane) expansion — External expansion uses adapters, connectors, and cables to connect like cards in separate Model 708A Switching Systems. Two types of external expansion are supported: external analog expansion and external analog expansion with control (master/slave). Refer to Figure 3-11. A master/slave connection of up to five switching matrices is an extension of the rows (up to 8 rows by 60 columns). Individual rows and columns can also be connected between cards or between switching matrices. External analog expansion is discussed in paragraph 3.5.3. To expand using analog expansion with control (master/slave), first expand using external expansion (paragraph 3.5.3), and then complete using control expansion (paragraph 3.5.4).

Use Table 3-6 to determine the type of row expansion for specific matrix cards.

NOTE

Column expansion (including partial matrix expansion) for all matrix cards is accomplished externally to the backplane (refer to paragraph 3.5.3).

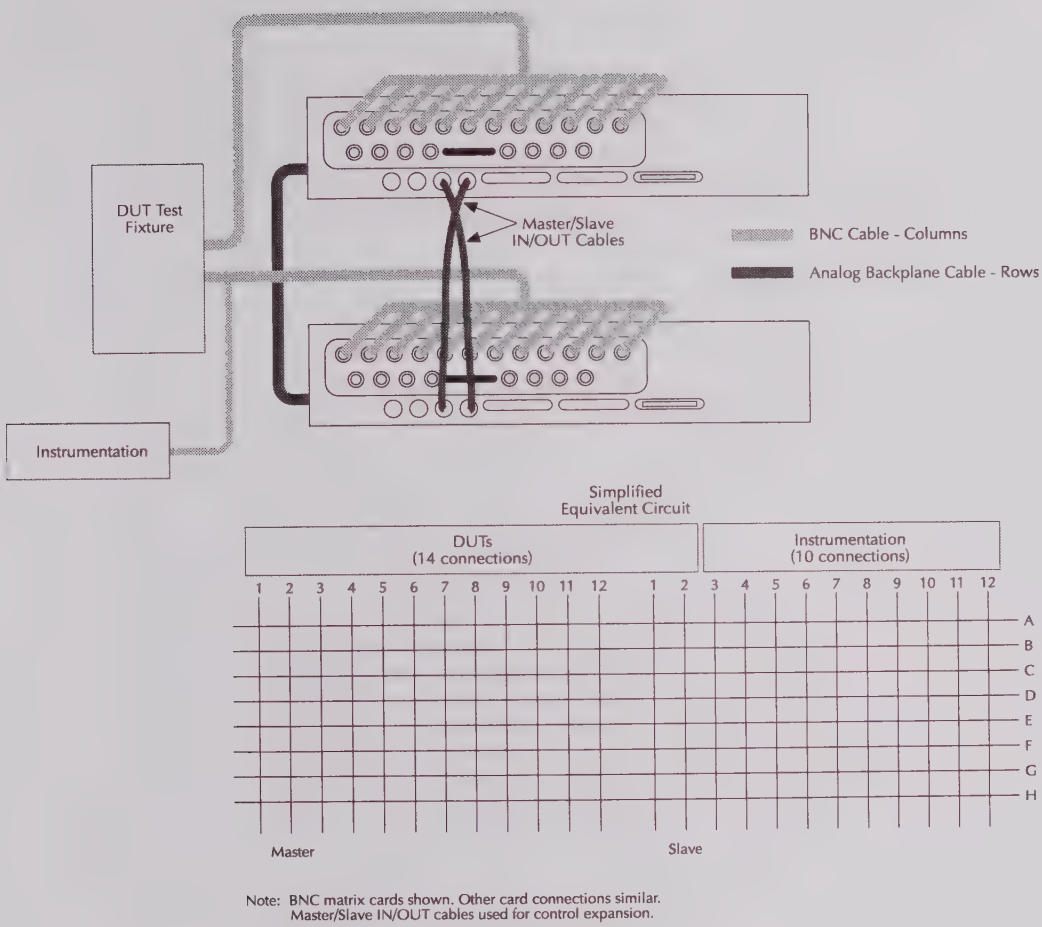
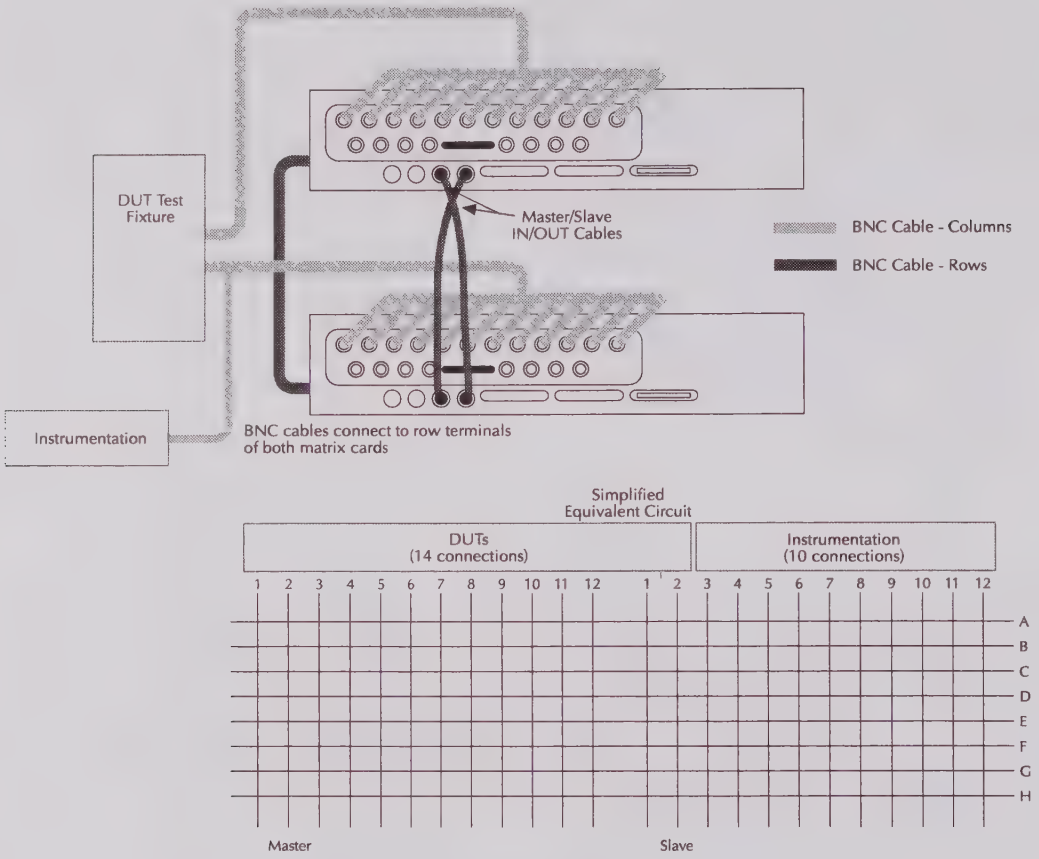


Figure 3-10
Sample backplane expansion



NOTE: BNC matrix cards shown. Other card connections similar.

Figure 3-11
Sample external (to backplane) expansion

Table 3-6
Matrix expansion

Card family	Model	Form	Connectors
Universal	7070[1]	96 Open Collector Drivers	20 quick disconnect with 3 screw terminals
General purpose	7071[2]	8 × 12 Matrix Card	Quick disconnect using 38-pin connectors or screw terminals
	7071-4[2]	Dual 4 × 12 Matrix Card	Quick disconnect using 38-pin connectors (or screw terminals on rows)
	7074-D[2]	Eight 1 × 12 Multiplexer Card	Bank—Four 75-pin connectors Row—One 38-pin connector
	7074-M[2]	Eight 1 × 12 Multiplexer Card	Bank—Four 75-pin connectors Row—One 38-pin connector
	7075[2]	Eight 1 × 12 Multiplexer Card	25-pin subminiature D connector
	7076[2]	Dual 4 × 12 Matrix Card	25-pin subminiature D connector
Semiconductor	7072[1,2]	8 × 12 Matrix Card	3-lug triaxial
	7072-HV[1,2]	8 × 12 Matrix Card	3-lug triaxial
	7172[1]	8 × 12 Matrix Card	3-lug triaxial
	7174[1]	8 × 12 Matrix Card	3-lug triaxial
Coaxial	7073[3]	8 × 12 Matrix Card	BNC
	7077[2]	8 × 12 Matrix Card	BNC
	7173-50[1]	4 × 12 Matrix Card	BNC

NOTES:

1. Accomplish row control expansion for this card through external cabling/connections (refer to paragraph 3.5.3).
2. Accomplish row expansion automatically for this card through analog backplanes. Manufacture a 50-pin cable and connect backplanes of each Model 708A using the 50-pin connector located on the backplane (refer to paragraph 3.5.2 for connection information and to paragraph 3.5.7 for information on the 50-pin cable).
3. Accomplish row expansion automatically for this card through analog backplanes. Manufacture a 20-pin cable and connect backplanes of each Model 708A using the 20-pin connector located on the backplane (refer to paragraph 3.5.3 for connection information and to paragraph 3.5.7 for information on the 20-pin cable).

3.5.2 Backplane row expansion

Use the following procedure as a guideline to connect two or more Model 708A Switching Systems containing like cards through the analog backplane. Matrix card rows (refer to Table 3-6, notes 2 and 3) may be connected together using this method.

NOTE

Analog backplane expansion does not expand control of separate Model 708A Switching Systems in a master/slave system. This is accomplished through control expansion (paragraph 3.5.4).

1. Determine expansion design. Refer to paragraph 3.5.5 for system expansion issues and to paragraph 3.5.8 for sample expanded matrices.
2. Remove power from all Model 708A Switching Systems and all circuitry. Disconnect power cords.
3. Make sure the Model 708A Switching Systems to be connected (up to five) have been properly configured. Refer to paragraphs 2.2 and 4.6.1.
4. Using Table 3-6, determine the type of cable needed to connect Model 708A Switching Systems through the connectors. The type of cable (20-pin or 50-pin) will be determined by the type of connectors specific to the cards to be used. Also determine approximate cable length by using the distance between each backplane connection as a minimum.

NOTE

The number of connectors used in the cable will depend on the number of Model 708A Switching Systems to be connected through the backplane.

Specifications exclude errors resulting from the cable.

5. Construct cable (paragraph 3.5.7).
6. Connect Model 708A Switching Systems through the appropriate backplane connectors.
7. If the system is being set up as a master/slave, continue expansion. Refer to paragraph 3.5.4.

3.5.3 External expansion

Use the following procedure as a guideline to connect two or more Model 708A Switching Systems containing like cards externally to the backplane. Matrix card rows or columns may be connected using this method.

NOTE

External expansion does not expand control of separate Model 708A Switching Systems in a master/slave system. This is accomplished through control expansion (paragraph 3.5.4).

1. Determine expansion design. Refer to paragraph 3.5.5 for system expansion issues and to paragraph 3.5.8 for sample expanded matrices.
2. Remove power from all Model 708A Switching Systems and all circuitry. Disconnect power cords.
3. Make sure the Model 708A Switching Systems to be connected (up to five) have been properly configured. Refer to paragraphs 2.2 and 4.6.1.
4. Using Table 3-6 and Table 3-7, determine the type of cable, the approximate cable length needed, and the distance between each connection needed to connect the Model 708A Switching Systems.

NOTE

The number of connectors used in the cable will depend on the number of Model 708A Switching Systems to be connected through the backplane.

Specifications exclude errors resulting from the cable.

5. Connect Model 708A Switching Systems through the appropriate connectors.
6. If setting up system as a master/slave configuration, continue expansion. Refer to paragraph 3.5.4.

Table 3-7
Model 708A external expansion cables

Model no.	Description	Expansion
7078-KIT 7078-MTC	Mass Terminated Cable Kit Mass Terminated Cable (20 ft.)	7071, 7071-4 rows/columns, 7074 rows
7078-TRX-3 7078-TRX-10	3-lug Triax-Triax Cable (3 ft.) 3-lug Triax-Triax Cable (10 ft.)	7072, 7072-HV, 7172, 7174 rows/columns
7051-2 7051-5	BNC-BNC Cable (2 ft.) BNC-BNC Cable (5 ft.)	7073, 7173-50 rows/columns
7074-KIT 7074-MTC	Mass Terminated Cable Kit Mass Terminated Cable (20 ft.)	7074 banks
7075-MTC	Mass Terminated Cable (10 ft.)	7075, 7076 rows/columns

3.5.4 Control expansion using master/slave configuration

Connect each Model 708A at the MASTER/SLAVE IN and OUT connectors using a Model 8501-1 or 8501-2 cable. Refer to paragraph 1.9 for cable description. If connecting two Model 708A Switching Systems in a master/slave arrangement, two cables will be needed. If connecting five Model 708A Switching Systems in a master/slave arrangement, five cables will be needed. Refer to Figure 3-12. Column locations for a fully expanded Model 708A are shown in Figure 3-13.

1. Connect the master unit's MASTER/SLAVE OUT to the first slave unit's MASTER/SLAVE IN.
2. If expanding to more than two Model 708A Switching Systems, connect the first slave unit's MASTER/SLAVE OUT to the second slave unit's MASTER/SLAVE IN. Continue connecting in this fashion to the last slave unit.
3. Connect the last slave unit's MASTER/SLAVE OUT to the master unit's MASTER/SLAVE IN.

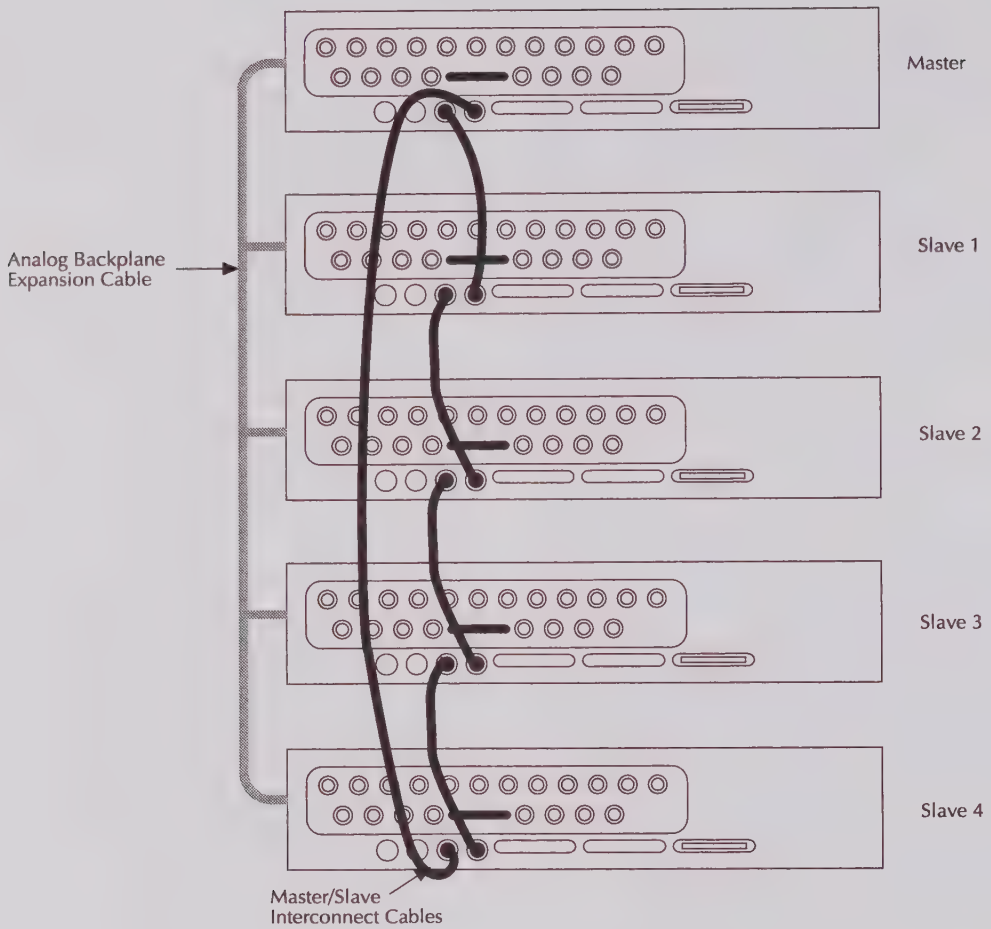


Figure 3-12
Sample of master/slave interconnect cables – five Model 708A switching systems

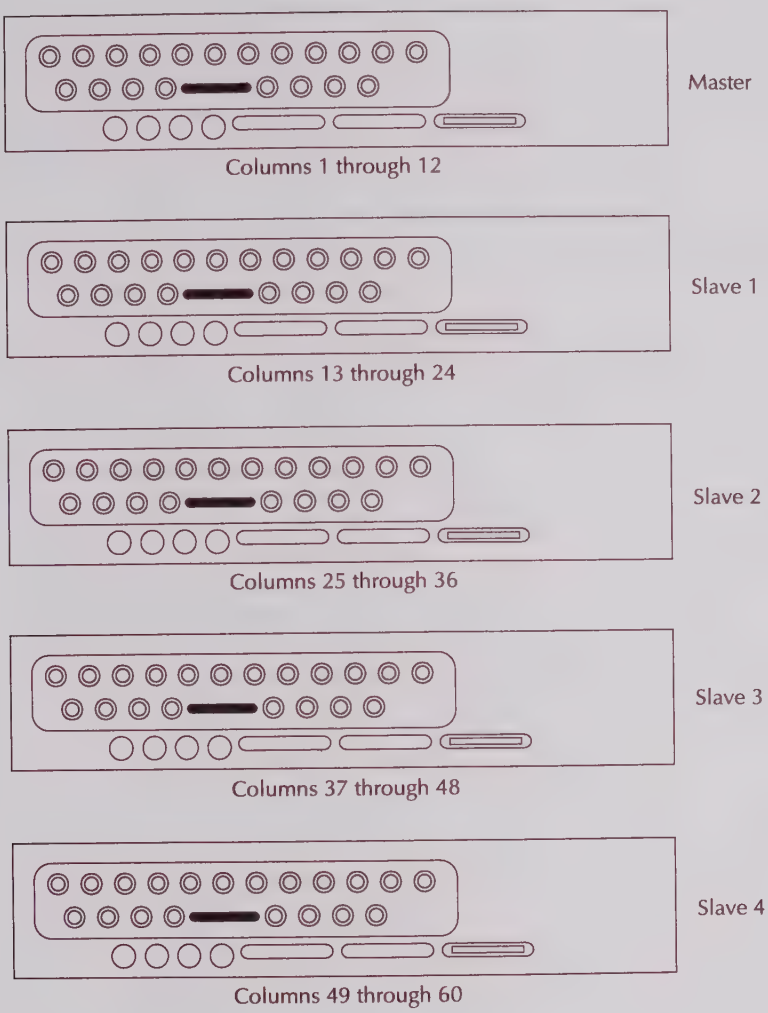


Figure 3-13
Master/slave column locations

3.5.5 System expansion issues

Matrix expansion by Model 708A Switching Systems affects system specifications and speed. The extent of affect depends on the size and configuration of the switching system.

Backplane row expansion decreases isolation among like cards and increases offset current. Isolation relays (on the Model 7072) and backplane jumpers (for general purpose rows) help decrease these effects.

Expansion of units along rows or columns also degrades the isolation and offset current specifications because of the number of parallel paths and relays on each signal line.

Issues that affect system speed include:

Relay settling time — Each matrix card has a predefined relay settling time. When card types are mixed in a system, the longest settling time is in effect.

Bus communication — A master/slave setup responds slower to bus commands because all communication is through the master unit and the data transmission among the units is verified with handshaking. Table 3-8 compares some typical response times.

Table 3-8
Response time comparison

Action	Stand-alone	Master with four slaves
Respond to bus command to close single relay.	<15ms	<55ms
Download one setup to 708A.	50ms typical	—

3.5.6 Documenting system configuration

With the connection flexibility of the matrix topology and the expansion/isolation options of the Model 708A, documentation of the system configuration is important.

An example table for tracking card connections and expansion is shown in Table 3-9. Use the top portion of the table to note system operation and size, the FROM/TO portion to list card row and column connections, and the lower portion for notes concerning expansion and operation.

Table 3-9
Model 708A switching system card configuration worksheet

Card model number: _____

Stand-alone _____

Master _____ Slave 1 _____ Slave 2 _____ Slave 3 _____ Slave 4 _____

System size:
Total crosspoints _____ rows _____ columns _____ IEEE address _____

FROM (Instrument connection or DUT pin)	External Card Connection	TO (Instrument connection or DUT pin)
	Row A	
	B	
	C	
	D	
	E	
	F	
	G	
	H	
	Column 1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	
	9	
	10	
	11	
	12	

Expansion:

___ Backplane bus (rows through ribbon cable)
___ Point to point writing (rows/cols.)
___ Triax cable (rows/cols.)
___ Mass terminated cable (rows/cols.)
___ BNC coax cable (rows/cols.)
___ Partial matrix expansion

Notes:

3.5.7 Analog backplane cable construction

The analog backplane of the Model 708A Switching System has two expansion connections (see Figure 3-14). Each connection is part of a printed circuit board with wire traces 0.100 inches apart. Use these connections to expand Model 708A rows to the rows of other Model 708A Switching Systems. The 20-pin connection is used for expansion of coaxial matrix cards [does not apply to the Model 7077 (50 pin) or the Model 7173-50 (no automatic expansion)]. The 50-pin connection is used for expansion of general purpose cards. Table 3-6 contains the model numbers of all cards supported by the Model 708A and also describes the appropriate method of expansion.

NOTE

Analog backplane expansion does not expand control of separate Model 708A Switching Systems as a master/slave system. This is accomplished through control expansion (paragraph 3.5.4).

Recommended cable parts (or equivalent)

NOTE

The 20-pin cable does not maintain the 50Ω characteristic impedance of the analog backplane (the 20-pin cable is intended for DC expansion).

Note: The following cables are available from 3M Corporation.

20-pin cable

3365/20 (3M) — 28 AWG ribbon cable rated at >200VDC.

3461-001 (3M) — 0.1 inch card-edge connector with a current rating of 1A > 200VDC (one connector required for each Model 708A).

3448-54 (3M) — Strain relief (one strain relief required for each Model 708A).

50-pin cable

3365/50 (3M) — 28 AWG ribbon cable rated at >200VDC.

3415-0001 (3M) — 0.1 inch card-edge connector with a current rating of 1A > 200VDC (one connector required for each Model 708A).

3448-54 (3M) — Strain relief (one strain relief required for each Model 708A).

NOTE

The number of connectors/strain reliefs used in the cable will depend on the number of Model 708A Switching Systems to be connected through the backplane.

Specifications exclude errors resulting from the cable.

When manufacturing the cable:

- Keep the cable length as short as possible. Make sure adequate length is provided to span the distances between the Model 708A Switching Systems. If the Model 708A Switching Systems are not rack mounted, provide extra clearance if physical layout of the mainframes is subject to change.
- Make sure adequate cable is allowed between each connector placed on the cable.
- Make sure pin 1 of each connector is aligned for pin 1 on each Model 708A connection. The connectors/connections are not keyed.

3.5.8 Sample expanded matrices

Figures 3-15 through 3-18 contain sample expanded matrix systems. Use these samples as a guide when designing a matrix system. Refer to paragraph 3.4 for instruments and DUT considerations while designing a matrix system.

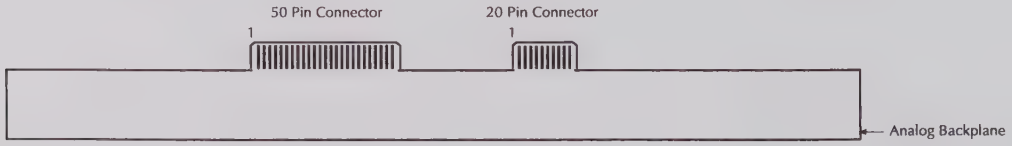


Figure 3-14
Analog backplane expansion connectors

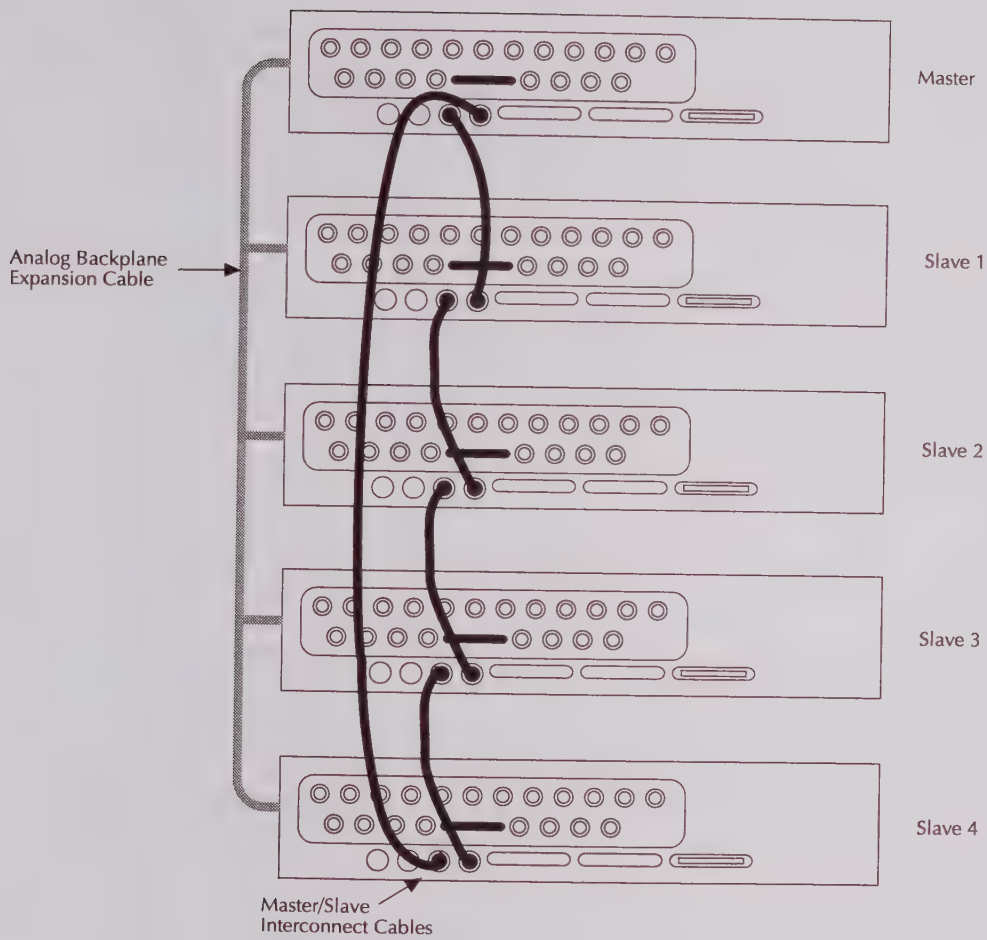
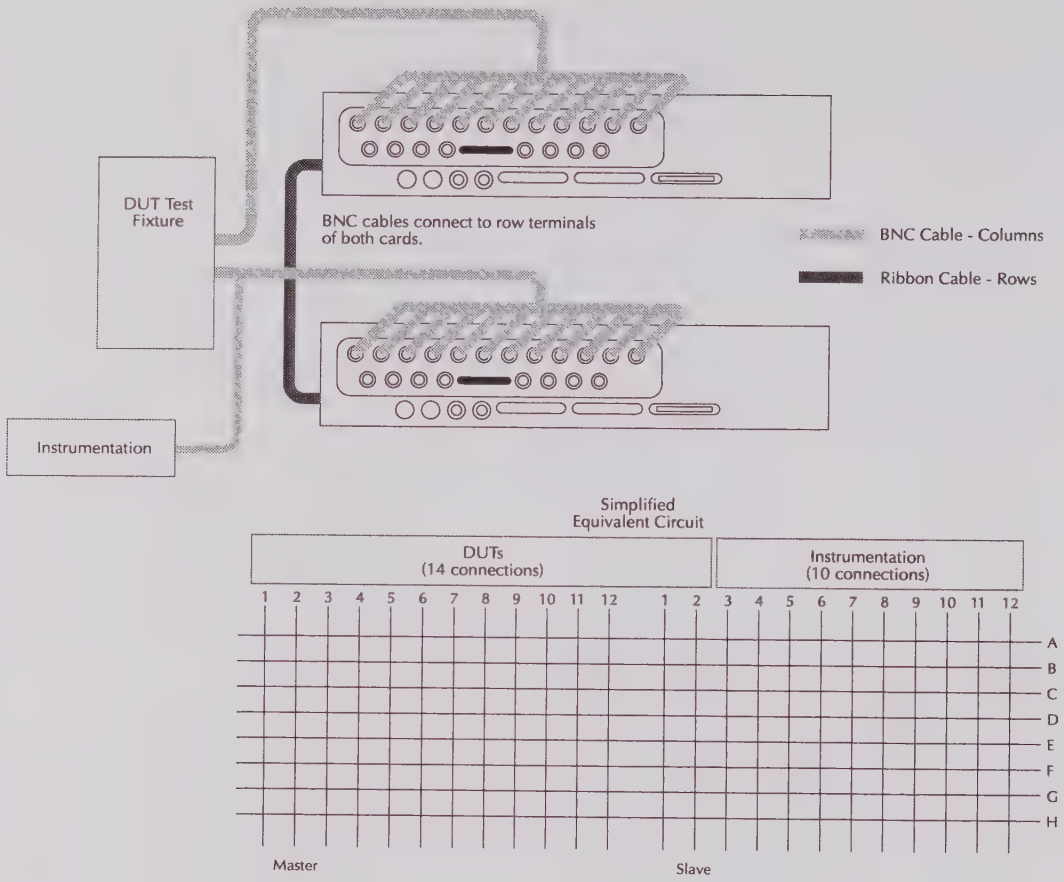
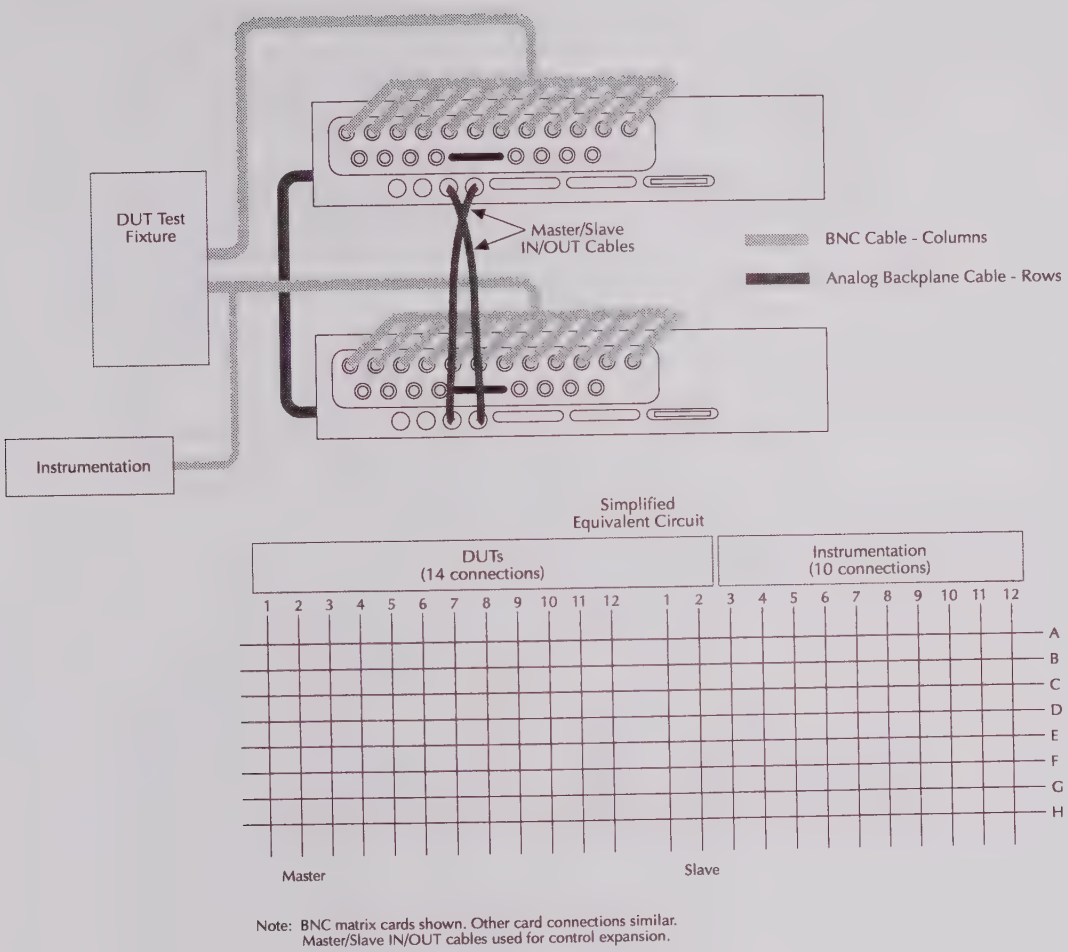


Figure 3-15
Backplane expansion cable – five Model 708A switching systems



Note: BNC matrix cards shown. Other card connections similar.

Figure 3-16
External row expansion – two stand-alone Model 708As



Note: BNC matrix cards shown. Other card connections similar.
Master/Slave IN/OUT cables used for control expansion.

Figure 3-17
Sample backplane expansion

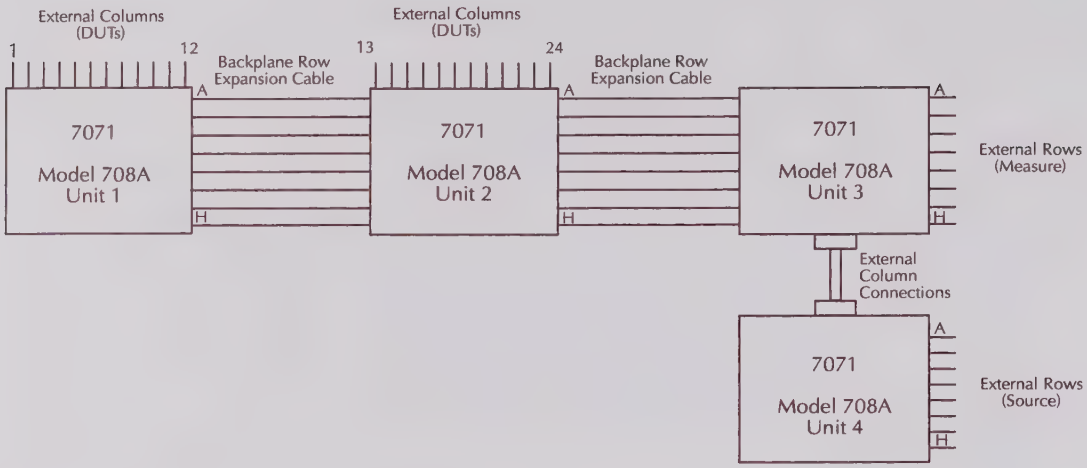


Figure 3-18
Partial matrix expansion example

3.6 Basic switching overview

The following paragraphs provide a step-by-step procedure for editing a matrix setup, storing it in memory, and sending the setup to the relays. The steps described are performed over the IEEE-488 bus. Refer to Section 4 for more operation information, including master/slave configurations.

3.6.1 Power-up

Connect the instrument to a grounded AC outlet using the supplied power cable and turn on the unit. The Model 708A will perform a power-up self-test to check ROM, RAM, card configuration, stored setups, master/slave loop, indicators, and displays.

When the self-test is complete, the Model 708A is configured with:

- All relays opened.
- The crosspoint display showing present relay setup.
- RELAY STEP to 000 (a pseudo setup memory that is cleared at power-up and sent to the relays).
- MEMORY STEP to 001.

For a complete listing of power-up defaults, refer to paragraph 4.3.

3.6.2 Selecting make/break and break/make rows

Select make-before-break, break-before-make, or the don't care operation for the rows. Don't care is selected by deselecting a make/break or a break/make state. The selections will be in effect for all relay switching, even if a stored setup is not used. As a general rule, use make/break operation for current sources and break/make operation for voltage sources.

Program the setup using the commands V and W as explained in paragraphs 5.9.21 and 5.9.22.

3.6.3 Modifying a relay setup

Use the Z — copy command (paragraph 5.9.25) to copy the desired setup to the relays and the display.

If you have the optional light pen, toggle the state of a crosspoint LED by holding the light pen perpendicular to and touching the front panel overlay, and pressing the light pen button. Continue editing with the light pen until the crosspoint display shows the desired configuration.

You also may use the C — close and N — open commands (paragraphs 5.9.4 and 5.9.13) to control the status of the relays.

3.6.4 Storing relay setup and applying setup to relays

To store the modified setup, use the Z — copy command (paragraph 5.9.25) to copy the desired setup from the relays to a setup number, which is specified when sending the Z command.

4 Operation

4.1 Introduction

This section contains a complete, detailed description of each front and rear panel aspect of the Model 708A.

4.2 Setup data paths

The design of the Model 708A is optimized for high speed switching of relay setups for matrices with a maximum of 8 rows by 12 columns (one unit) to 8 rows by 60 columns (five units). If no rows are selected for make/break or break/make operation, previously stored setups can be switched to the relays at a rate of up to 200 setups per second.

Besides the triggering of stored setup data to the relays, setup data can be routed to and from the sources and destinations shown in Figure 4-1. The data paths are selected by the IEEE-488 bus operations listed in Table 4-1.

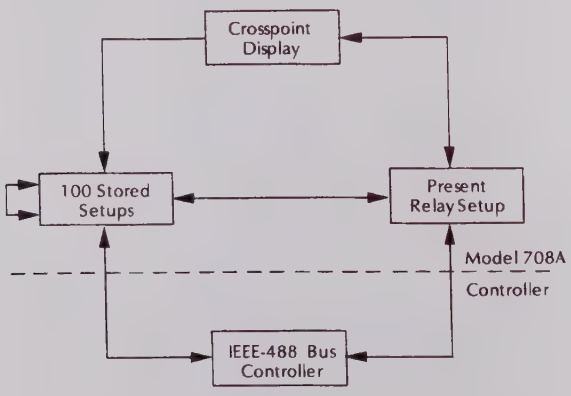


Figure 4-1
Paths for relay setup data

In addition to other front and rear panel operations, this section describes setup data transfers that are performed from the Model 708A front panel. Section 5 describes the bus operations that transfer setup data.

Table 4-1
Setup data paths

Setup data path	Action required
Display-Memory	Bus command
Display-Relays	Front panel COPY key (Note 1)
Memory-Display	Automatic operation (Note 2)
Memory-Relays	Bus command or any valid trigger
Memory-Controller	Bus command
Memory-Memory	Bus command
Relays-Display	Automatic operation (Note 3)
Relays-Memory	Bus command
Relays-Controller	Bus command
Controller-Memory	Bus command
Controller-Relays	Bus command

Notes:

1. Generation of the automatic copy is selected by a front panel key. COPY LED is lit.
2. The automatic operation is generated if the displayed setup has been changed by a bus command and has not been modified from the front panel.
3. The automatic operation is generated if the displayed setup has been changed by a trigger or bus command and has not been modified from the front panel.
4. All controller modifications to setups are reflected on the crosspoint display if the affected setup is presently being displayed.

4.3 Power-up procedure

4.3.1 Line power connections

Line voltage supply

The Model 708A Switching System can be operated from line voltages of 100-240VAC at line frequencies of 50-60Hz.

Line power connections

Using the supplied line power cord, connect the switching matrix to an appropriate AC power source. The female end of the cord connects to the AC receptacle on the rear panel of the instrument. The other end of the cord connects to a grounded AC outlet.

WARNING

The Model 708A must be connected to a grounded outlet to maintain continued protection against possible shock hazards. Failure to use a grounded outlet could result in personal injury or death due to electric shock.

CAUTION

Do not operate the instrument on a line voltage outside the indicated range, or instrument damage could occur.

4.3.2 Power switch

To turn on the power, push in the front panel POWER switch. Power is on when the switch is at the inner (1) position. To turn power off, press POWER a second time.

WARNING

The position of the POWER pushbutton indicates the power status of the Model 708A Switching System. The status of the crosspoint display and the other LEDs are not indications of power being applied to the Model 708A. Failure to correctly recognize the power status of the Model 708A could result in serious injury or death due to electrical shock.

4.3.3 Power-up self-test and error conditions

During the power-up cycle, the instrument performs the following tests. The first five operations are transparent to the user unless an error occurs.

1. A checksum test is performed on ROM, and a read/write test is performed on RAM. If an error is found, the self-test continues and the unit error LED (ERR) lights along with crosspoint LED D6 (ROM error) or D7 (RAM error). Override either type of error with a front panel keypress. The Model 708A will attempt normal operation.
2. The Model 708A reads identity information from the installed card and performs a checksum test on the data. If the checksum test fails on the card, the error LED (ERR) lights along with crosspoint LED D8. Override with a front panel keypress. An empty slot will not produce an error.
3. A checksum test is performed on all setups in memory. If the instrument detects a checksum error in one or more stored setups, the error LED (ERR) lights along with crosspoint LED D9. The instrument clears the crosspoints bits of the setup(s) in error. The LEDs remain lit until a key is pressed.

NOTE

The setup error condition may be an indication of a low battery. Cycle power off and on. If the condition reappears, refer to paragraph 7.5 for the battery replacement procedure.

4. The present card configuration is compared with the unit's previous configuration. If there is a change, the 100 setups in memory are reformatted. The front panel display is blanked out during this time. Crosspoint closures are not affected. The storage setup for the different cards is changed.
5. If the unit was previously programmed as a stand-alone or slave unit, it powers up as a stand-alone. If the unit was previously programmed as a master, it checks for additional units in a serial looped configuration and tries to make them slave units. Refer to paragraph 4.6.4 for information concerning turning on a master/slave configuration. The error LED (ERR) and crosspoint LED D3 light if there is not a closed loop (the Model 708A can be looped back to itself). Any keypress or IEEE-488 bus operation will allow the unit to continue as a stand-alone unit.
6. The instrument performs the display test, where it illuminates all crosspoint LEDs and all other LED indicators.

4.3.4 Power-up configuration

After the power-up tests and display messages are completed, the Model 708A assumes the following specific operating states:

- All relays open.
- Crosspoint display shows present relay setup.
- Relay Step to 000 (a pseudo setup memory that is cleared at powerup and sent to the relays).
- Memory Step to 001.
- Triggers are disabled.

Table 4-2 summarizes the power-up configuration for the unit. The entire power-up process takes approximately five seconds to complete.

4.3.5 Master/slave power-up

The power-up sequence for Model 708A mainframes can be summarized as follows:

- Units previously programmed as stand-alones or slaves power up as stand-alones.
- A unit previously programmed as a master powers up as a master and tries to initiate a loop connection. If it is successful, other units in the loop become slaves. If it is not successful, the error LED (ERR) illuminates and the unit reverts to stand-alone operation.

To connect and power up a master/slave configuration for the first time, follow these steps:

1. Connect up to five mainframes in a daisy-chain (MASTER/SLAVE OUT of one unit to MASTER/SLAVE IN of next unit). Refer to paragraph 3.5.4 for more information.
2. Power down each unit.
3. From the rear panel of the desired master unit, set the IEEE-488 address to 30 plus the present value. This action identifies the master unit while keeping the address at the previous number, which is the master's IEEE-488 setting minus 30.
4. Power up all the Model 708A Switching Systems.

During this initial and all subsequent power-ups of master/slave configurations, connected Model 708A Switching Matrices wait until all units have power before initializing. It is not necessary to turn on the master unit last.

CAUTION

When it is necessary to cycle power on a slave unit, turn off all units in the master/slave configuration. This procedure prevents the open communication and control loop from putting the slave unit in an undesirable state.

Table 4-2
Power-up, reset, and factory defaults

Parameter	Power-up/reset default	Factory default
Relays	All opened	All opened
Stored Setups	Unchanged	All cleared
Relay Step	000	000
Memory Step	001	001
Digital Output	000	000
Digital Power	Unchanged (user selectable— Jumper W101 selects internal/external power)	Internal
External Trigger	Falling edge	Falling edge
Matrix Ready	Active low	Active low
Master/Slave	Unchanged (if successful)	Unchanged
IEEE-488 Address	Unchanged	18
Programmed Settling Time	0ms	0ms
Make/Break Rows	Unchanged	None selected
Break/Make Rows	Unchanged	None selected
Trigger Enable	Disabled	Disabled
Trigger Source	External	External

4.4 Display

4.4.1 Error LED

Errors are signaled when the error LED (ERR) illuminates. Use the U1 — error status command (paragraph 5.9.20) to retrieve the cause of the error. Table 4-3 lists Model 708A error conditions. Where applicable, the necessary corrective action is also given in the table.

4.4.2 IEEE-488 status indicators

The TALK, LSTN, and REM LEDs shown in Figure 4-2 indicate modes when the Model 708A is being programmed over the IEEE-488 bus. The TALK and LSTN indicators show when the unit has been addressed to talk or listen. These talk and listen commands are derived from the unit's primary address. REM turns on to show when the unit is placed in remote by addressing it to listen. All front panel controls except LOCAL and POWER are inoperative when REM is on. Local operation is restored by pressing LOCAL unless the IEEE-488 LLO (local lockout) command is in effect. See Section 5 for details about IEEE-488 bus operation.

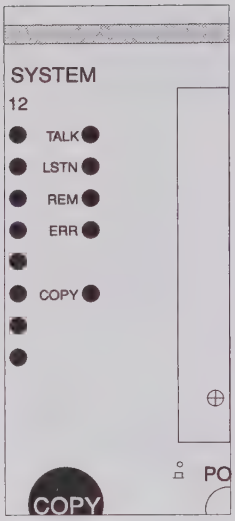


Figure 4-2
IEEE-488 status indicators

Table 4-3
Error conditions

Error	Description	Corrective action
Card ID Error*	Checksum test failed on a card.	Remove card identified by all crosspoint LEDs lit.
IDDC	Invalid device-dependent command.	Send only valid commands (see Section 5).
IDDCO	Invalid device-dependent command option.	Send only valid command options (see Section 5).
Invalid Input	Invalid crosspoint address, setup location, make/break or break/make row, or parameter out of range.	Enter valid data.
M/S Error*	Error in master/slave communication loop (overrun, parity, framing, count imbalance, or time-out).	Check for a closed loop of MASTER/SLAVE OUT to MASTER/SLAVE IN.
M/S Loop Down	One or more units connected in master/slave loop are not powered up.	Turn on all units or reconfigure master/slave loop.
Not in Remote	"X" character received over IEEE-488 bus, but Model 708A is not in remote.	Put Model 708A in remote.
RAM Fail*	Self-test detected error in RAM.	See troubleshooting in Section 7.
ROM Fail*	Self-test detected checksum error in ROM.	See troubleshooting in Section 7.
Setup Error*	Self-test detected checksum error in stored setup. Battery may be low.	Affected setup is cleared, and then Model 708A proceeds normally.
Trig Overrun	An additional trigger was received before the Model 708A asserts the READY signal.	Check the READY bit in the serial poll byte.

* Error LED (ERR) remains lit until next operation.

4.4.3 Crosspoint display LEDs

As shown in Figure 4-3, the crosspoint display has one LED for each crosspoint of a card. Each block has 8 rows (A-H) by 12 columns (1-12) of LEDs. The display LEDs show the present open or closed relay states, or the on/off states of a setup presently being edited. The on/off states of crosspoint LEDs can be changed by commands over the bus or by the optional light pen. Modified displays can be stored in memory or sent to the relays.

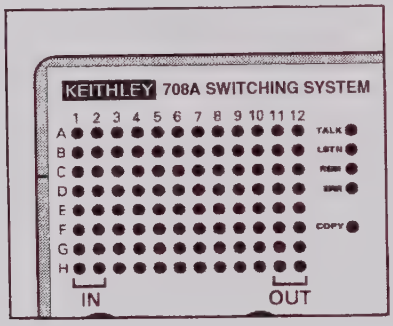


Figure 4-3
Crosspoint display LEDs

4.4.4 Light pen

The light pen is an optional input device for toggling the on/off states of crosspoint display LEDs or digital I/O status LEDs. One light pen is used to control the LEDs of all units in a master/slave system.

As shown in Figure 4-4, the light pen connector plugs into the front panel of stand-alone or master units. Remove the light pen by pressing the button on the connector plug while pulling out the plug. Mount the light pen holder on a handle of the Model 708A by tightening the allen-head screw shown in Figure 4-4.

To toggle the state of a crosspoint LED or change the digital I/O status LED with the light pen, perform the following steps:

CAUTION

When changing setups, use caution when the COPY key is enabled (the corresponding COPY LED will be lit). Inadvertent connections may be copied to the relays causing instrument damage.

1. Hold the light pen as you would an ordinary pen.
2. With the light pen perpendicular to the front panel overlay at the desired LED, press the button on the pen's barrel.
3. Proper usage will toggle the state of the LED. If the button is pressed while not on an LED, no change will be made to the Model 708A Switching System display (or relays if COPY LED is lit).

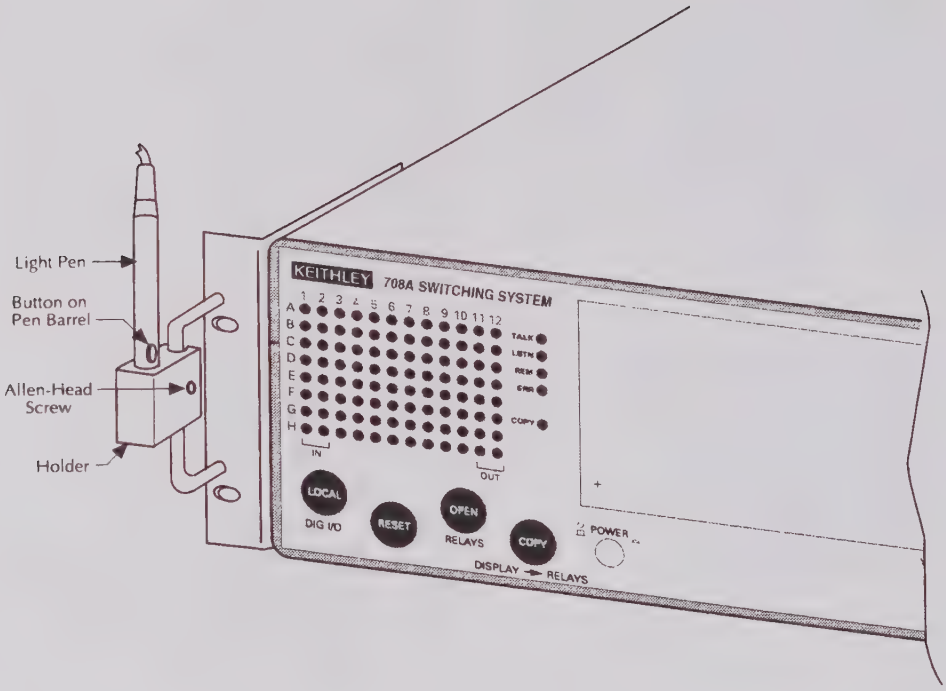


Figure 4-4
Light pen

4.5 Crosspoint display

If the displayed setup is modified by trigger or IEEE-488 commands, the crosspoint display changes automatically. If editing a setup, changes to its source do not appear.

CAUTION

When changing setups, use caution when the COPY key is enabled (the corresponding COPY LED will be lit). Inadvertent connections may be copied to the relays causing instrument damage.

4.5.1 Modifying

After choosing the source of the setup, a crosspoint display can be modified by turning on/off crosspoint LEDs with the light pen. If the COPY indicator is lit, these actions open or close relays immediately.

The maximum valid column number with a single unit is 12. If several mainframes are connected and programmed for master/slave operation, the maximum column can be up to 60 (with five units).

The optional light pen can also be used to turn on and off crosspoint LEDs. Hold the light pen perpendicular to the front panel overlay at the desired LED and press the button on its barrel. This action toggles the state of the LED.

The maximum number of simultaneously closed crosspoints depends on the specified drive current per crosspoint of each card. The total relay drive current required per mainframe cannot exceed 5A.

4.5.2 Copying

The setup data displayed on the crosspoint LEDs can be stored in the non-volatile memory of the Model 708A or can be sent directly to the relays by pressing the COPY key or by sending a device-dependent command (DDC). See paragraph 5.9.25 for more information.

With the DDC, the displayed crosspoint configuration is stored at the setup location specified when issuing the command. It overwrites the present setup data at that location. An invalid input error occurs if you try to copy to a setup location below one or above 100.

In master/slave configurations, each unit stores its own portion of each stored setup.

When the COPY key is pressed or the COPY LED is lit, the displayed crosspoint configuration is sent to the relays. When the COPY LED is lit, any change to the crosspoint display is also sent to the relays at the same time. This action is apparent when scrolling through unmodified stored setups; the memory step and relay step fields will sequence together. For more information on these fields, refer to paragraph 5.8.

4.6 Operation control

4.6.1 Digital I/O ports

The TTL-compatible digital I/O port has sixteen data lines for inputs and sixteen data lines for outputs. The pinouts for the rear panel DB-25 connectors are shown in Figure 4-5. Status of the input lines is viewed and states of the output lines are programmed through the LED display using the LOCAL/DIGITAL I/O key and the optional light pen, or changed through the IEEE-488 bus. Figure 4-6 shows input and output configurations.

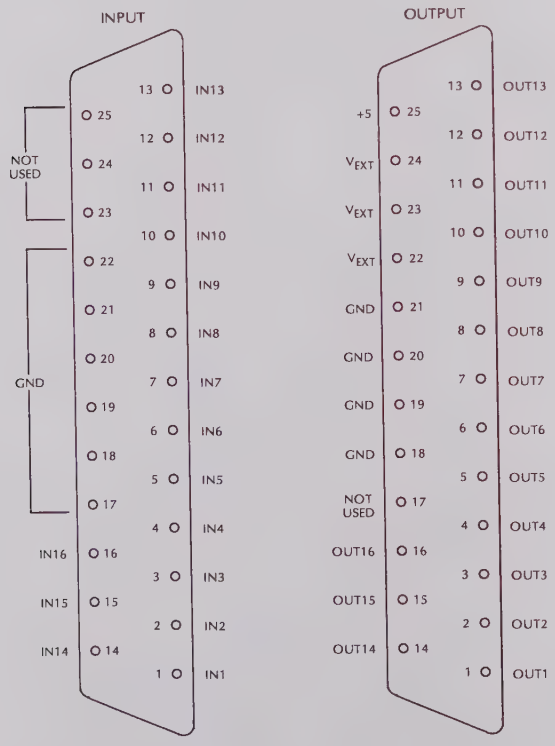


Figure 4-5
Pinouts – digital I/O ports

Digit inputs have an internal pull-up resistor. Open inputs will be indicated by logic high.

Digital outputs are negative true. When a logic high is programmed, the output goes low (sinks).

With master/slave configurations, only the digital I/O ports of the master unit are available for viewing and programming.

Digital I/O power supply jumper

Jumper W101 selects internal power supply (as shipped from factory) or external (user) supplied power supply. Refer to Section 7 for information on changing the power supply.

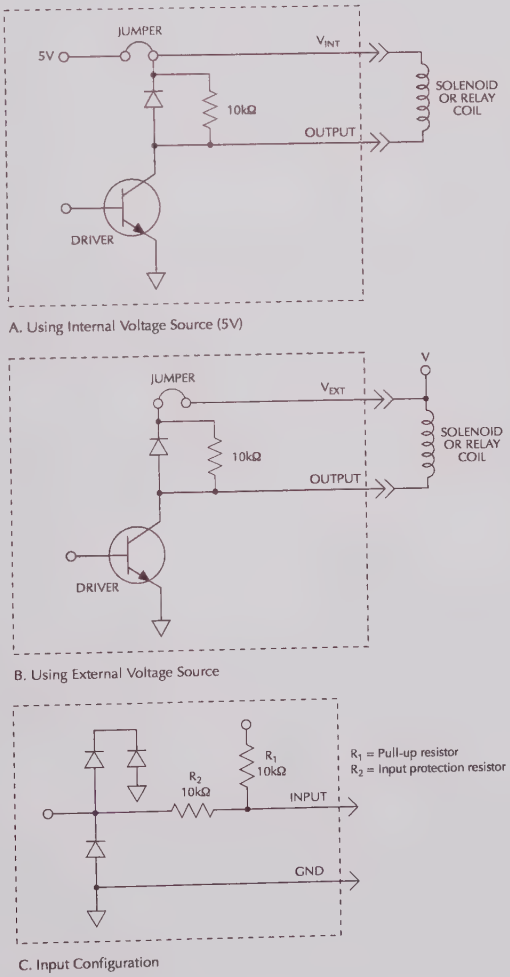


Figure 4-6
Input/output configurations

4.6.2 External trigger

If triggers are enabled and external trigger is selected as a source, a TTL-compatible pulse of at least 600ns duration at the rear panel EXT TRIG INPUT jack triggers the Model 708A. The input BNC jack is shown in Figure 4-7.

Figure 4-7
Rear panel BNC jacks

The unit can be programmed for which edge (falling or rising) of the external trigger pulse causes a transfer of stored setup data to the relays. Sample trigger pulses are shown in Figure 4-8. To select which pulse edge triggers, send a DDC. For more information, refer to paragraph 5.9.2.

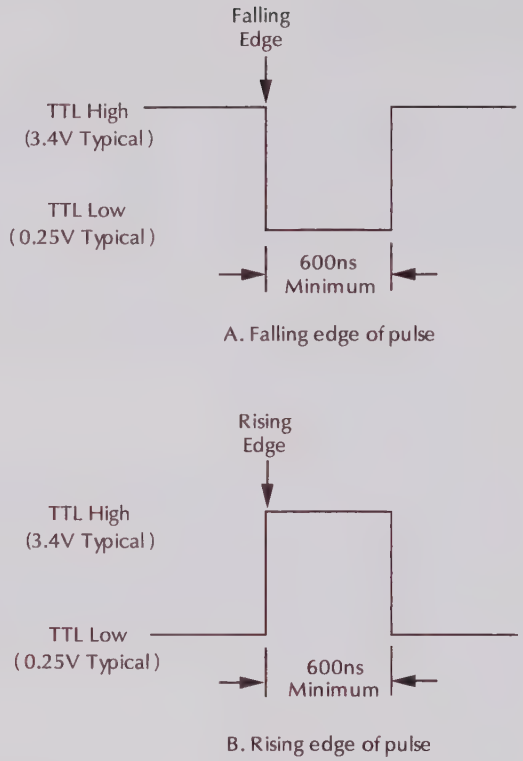


Figure 4-8
Sample external trigger pulses

In master/slave configurations, only the EXT TRIG INPUT port of the master unit is active. See paragraph 4.8 for more information on triggering the Model 708A.

4.6.3 Matrix ready output

The Model 708A provides a TTL-compatible signal at its rear panel MATRIX READY OUTPUT jack as shown in Figure 4-7. The MATRIX READY signal goes false when relays are switched and goes true at the end of the programmed settling time. As described in paragraph 4.8, this is also after the relay settling time.

The unit can be programmed for a high- or low-true MATRIX READY signal (Figure 4-9). To select the active state of the signal, send a DDC. For more information, refer to paragraph 5.9.3.

In master/slave configurations, the MATRIX READY signals of all units function, but only the master's MATRIX READY is an accurate signal.

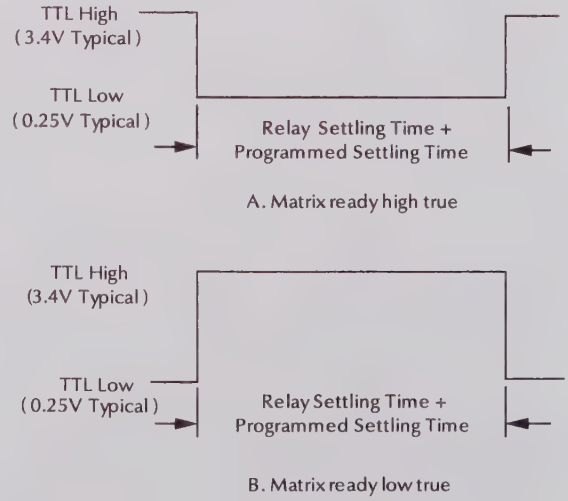
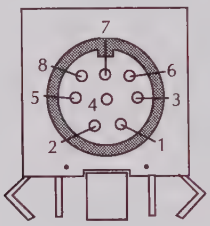


Figure 4-9
Sample matrix ready pulses

4.6.4 Stand-alone and master/slave

One method for expanding system size is to connect up to five switching systems in a master/slave configuration, where all units are daisy-chained for serial communication and control. System operations are performed through the master unit, either over the IEEE-488 bus or the master's front panel (including the light pen). A master/slave system appears as a single unit and IEEE-488 address with a maximum size of 8 rows by 60 columns. Select stand-alone or master/slave operation by setting the IEEE-488 addresses of the Model 708A Switching Systems. Use the rotary switches located on the rear panel of the Model 708A.

As described in paragraph 3.5.4, the MASTER/SLAVE OUT and MASTER/SLAVE IN rear panel connectors are used to connect DIN cables in a closed loop. The connector pinouts are defined in Figure 4-10. The rear panel IEEE-488 address switches are shown in Figure 4-11.



Pin	Master/Slave IN	Master/Slave Out
1	M/S TRIGGER (low true)	M/S TRIGGER (low true)
2	ALLREADY	ALLREADY
3	LPRESET (low true)	LPRESET (low true)
4	LPSENSE (low true)	LPSENSE (low true)
5	RxDATA	TxDATA
6-8	Chassis Ground	Chassis Ground

Figure 4-10
Master/slave connectors

Designate one unit to be master by adding 30 to the IEEE-488 address (selectable by rotary switches on the rear panel of the Model 708A). If the loop of DIN cables is not closed, the master's error LED (ERR) will light, and all units will remain as stand-alones.

CAUTION

When it is necessary to cycle power on a slave unit, turn off all units in the master/slave configuration. This procedure prevents the open communication and control loop from putting the slave unit in an undesirable state.

Figure 4-11
Rear panel – IEEE-488 address switches

Cycle power of all units in the master/slave loop to establish control of the slaves through the master. During master/slave operation, most front and rear panel controls of the slave units are inactive. Table 4-4 shows slave unit's control and indicator status.

Table 4-4
Slave unit controls, indicators, and connections

Switch, indicator, or connector	Slave unit status
Front Panel	
POWER	active
CROSSPOINT DISPLAY LEDs	active (display only)
LOCAL key	inactive
OPEN RELAYS key	inactive
TALK, LSTN, REM LEDs	inactive
Light Pen/Light Pen Connector	inactive
Rear Panel	
MASTER/SLAVE IN	active
MASTER/SLAVE OUT	active
EXT TRIG INPUT	inactive
MATRIX READY OUTPUT	active (timing accuracy may be inaccurate)
DIGITAL INPUT and OUTPUT	inactive (outputs set to low)
IEEE-488 INTERFACE	not used

The master unit communicates with the slaves only when necessary; it does not continuously monitor the status of the closed-loop configuration. Hence, a disconnected master/slave loop cable will not be detected and the ERR LED will not be lit until the master attempts to send or receive data around the loop. To determine if a master/slave error has occurred, send a DDC (refer to paragraph 5.9.20). The steps to recover from an master/slave error are:

1. The master stops processing IEEE-488 bus commands, returns to stand-alone operation, and terminates.
2. The slave units remain the same as before the error occurred.

3. To re-initialize the loop, make sure master/slave cables are secure, and cycle power of all units.

4.6.5 IEEE-488 bus address

The Model 708A communicates over the IEEE-488 bus through the rear panel connection shown in Figure 4-12. When connected to a bus controller, instrument operating modes can be programmed. Note that IEEE-488 common is always grounded.

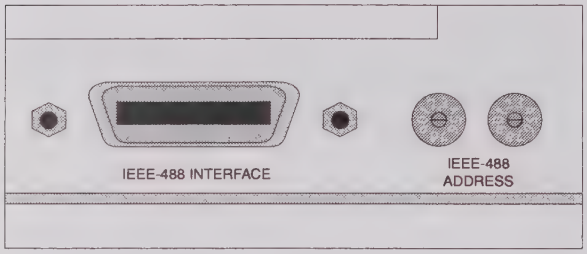


Figure 4-12
IEEE-488 bus connector and rotary selection switches

Two rotary switches on the rear panel of the Model 708A are used to set the IEEE-488 address. One switch is used to set each digit of the address. The primary address of the Model 708A is factory set to 18, but it may be set to any value between 0 and 30 (between 30 and 60 for a master unit) as long as address conflicts with other instruments or the bus controller are avoided. Actual master unit addresses for programming will be 30 less than the address set on the Model 708A.

To check the present primary address, look on the rear panel of the Model 708A. If the value is above 30, the actual IEEE-488 address will be 30 less. To change the address, perform the following procedure:

1. Power down the unit (stand-alone) or units (master/slave).
2. Change the position of the rotary switches (Figure 4-12) to the new address.

NOTE

Each device on the bus must have a unique primary address. Failure to observe this precaution could result in erratic bus operation. In a master/slave configuration, only the master Model 708A Switching System IEEE-488 address will be used. The IEEE-488 address is updated only at power-up.

Section 5 contains detailed information on operating the Model 708A over the IEEE-488 bus.

4.6.6 Hardware relay settling times

The card specification relay settling time is the time needed for the relays to actuate or release (including contact bounce time) and pass a clean signal. Since this specification is card dependent, the Model 708A must identify on power-up which cards are installed to determine the longest relay settling time in the system (stand-alone or master/slave). This value is not user-modified, but the total settling time for a switching operation can be lengthened by using the programmed settling time, as explained in paragraph 4.7.1.

To view the relay (hardware) settling time of the system, use the U6 — status command (paragraph 5.9.20).

See paragraph 4.8 for a discussion of settling times and triggers.

4.6.7 Self-test

The self-test program is used to check ROM, RAM, and allow inspection of the front panel LED indicators. This test is also part of the power-up sequence. If you want to run the test without cycling power, use the J0 — self test command (paragraph 5.9.9).

If there is an error in ROM or RAM, the ERR LED is lit until a keypress or bus operation. See Section 7 for troubleshooting procedures.

For master/slave configurations, all units are tested simultaneously, so you might have to run the test more than once to inspect all LED indicators. Program 99 will turn on all LEDs. This is done by setting the IEEE address switch to 99 and cycling power.

4.6.8 Factory defaults

A command can be used to return the Model 708A to the factory default conditions listed in Table 4-2. To initiate this action, use the R0 — restore defaults command (paragraph 5.9.17).

In master/slave configurations, all units return to factory defaults when this is sent to the master unit.

4.7 Selecting switching parameters

The Model 708A has three switching parameters that are user-modified: the programmed settling time, make-before-break rows, and break-before-make rows. The values of these parameters are in effect for all relay switching until they are changed. To modify the parameter, use the appropriate command.

4.7.1 Programmed settling times

The programmed settling time is a variable switching delay that can be used to lengthen the fixed delay of the relay (hardware) settling time. You can select, in 1ms increments, up to 65 seconds of additional switching delay.

If an additional trigger is received during this time, it is processed and the ERR LED is lit. At the end of the programmed settling time, the Model 708A sets the MATRIX READY output true.

To view the programmed settling time, use the U0 — status command (paragraph 5.9.20).

NOTE

The U6 command sends the longest hardware settling time for all matrix cards, and the U0 command sends the machine status word. The machine status word contains programmed settling times.

To change the programmed settling time, use the S — programmed settling time (paragraph 5.9.18). Use a value between 0-65000.

The programmed settling time is in effect for all crosspoint relay open or close operations until it is reprogrammed. Its effect on trigger response times is described in paragraph 4.8.

4.7.2 Make/break and break/make rows

Make-before-break switching of relays is defined as connecting a new circuit before disconnecting the present circuit. It is used to eliminate transients caused by switching between current sources. Break-before-make switching means to disconnect the present circuit before connecting a new circuit. It is used to avoid momentary shorting of two voltage sources. Both of these switching operations are supported by the Model 708A.

Rows of crosspoint relays are user-selectable for make/break, break/make, or don't care operation. The selections will be in effect for all switching until new choices are made. When make/break or break/make operation is chosen, the Model 708A automatically switches the crosspoint relays through intermediate setups to perform the following steps:

1. Crosspoints in break/make rows are opened.
2. Crosspoints in make/break rows are closed.
3. Crosspoints in make/break rows are opened.
4. Crosspoints in break/make rows are closed; crosspoints in don't care rows are opened or closed accordingly.

These steps are apparent to the user except for the increased settling time. If either make/break or break/make rows are not selected, the appropriate steps in the previous list are deleted and the total settling time decreases. Because make/break and break/make operations affect settling times and trigger response, these operations are further discussed in paragraph 4.8.

To change the status to break/make, make/break, or don't care, refer to paragraphs 5.9.21 and 5.9.22. Selecting a row for make/break de-selects it for break/make and vice versa. The row selection is in effect for all units connected in a master/slave configuration. The operations are listed in Table 4-5.

Table 4-5
Make/break and break/make operation

Present state	Action	Next state
Don't Care	Select Make/Break	Make/Break
	Select Break/Make	Break/Make
Make/Break	Select Break/Make	Break/Make
	De-select Make/Break	Don't Care
Break/Make	Select Make/Break	Make/Break
	De-select Break/Make	Don't Care

When switching current sources, use make/break operation to keep current flowing and eliminate switching transients. When switching voltage sources, use break/make operation to avoid momentary shorting of two paths together.

4.8 Triggering

When a Model 708A stand-alone or master unit is triggered, the stored relay setup from RELAY STEP+1 is sent to the relays. Triggers are enabled using the F1 command (paragraph 5.9.6).

The maximum trigger rate is specified with no make/break or break/make rows selected. As described in paragraph 4.8.2, additional switching delays are necessary with make/break or break/make operation.

4.8.1 Sources

The programmed trigger source provides the stimulus to increment to the next stored setup. Possible trigger sources include:

- External trigger pulse — An appropriate pulse, applied to the EXTERNAL TRIGGER INPUT jack on the rear panel, provides the trigger stimulus. The power-up default is set for external triggering.
- IEEE command triggers — IEEE-488 GET, X, or talk commands provide the stimulus when the appropriate source is selected.

Use the T — trigger command to select the trigger source (paragraph 5.9.19).

4.8.2 Overrun conditions

Once the instrument is triggered, it begins transferring relay setup data from mainframe memory to the cards. If a second trigger is received while the unit is still transferring data, a trigger overrun condition will occur. In this case, the second trigger is not processed, and the unit's ERR LED illuminates. Use the U1 — error status command (paragraph 5.9.20) to retrieve the cause of the error.

After the time required for transferring relay data has elapsed, the Model 708A is able to process another trigger. If a trigger is received before the programmed setting time has elapsed, a not settled error will result. Use the U1 — error status command (paragraph 5.9.20) to retrieve the cause of the error.

Figure 4-13 shows an example setup change and a timing diagram of the READY (for trigger) pulse and a high true MATRIX READY pulse when the Model 708A is processing the trigger. The status of these signals is available in the serial poll byte (see Section 5). This timing is for setups with no make/break or break/make rows.

When either make/break or break/make operation is selected, the Model 708A switches through an intermediate setup to ensure proper relay operation. If only make/break rows are selected, the Model 708A performs the following steps:

1. Closes crosspoints in make/break rows yielding an intermediate setup.
2. Opens crosspoints in make/break rows and opens/closes crosspoints in don't care rows yielding the desired setup.

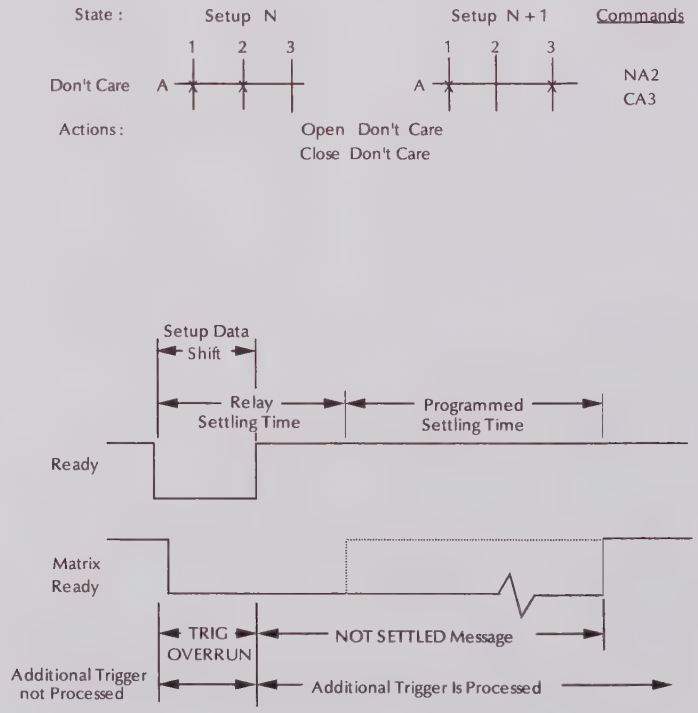


Figure 4-13
Timing without make/break and break/make rows

If only break/make rows are selected, the Model 708A performs the following steps:

1. Opens crosspoints in break/make rows yielding an intermediate setup.
2. Closes crosspoints in break/make rows and opens/closes crosspoints in don't care rows yielding the desired setup.

An example of these operations is shown in Figure 4-14 with the corresponding timing diagram. By comparing Figure 4-13 and Figure 4-14, you can see that the intermediate setup needed for make/break or break/make causes a delay in the assertion of READY and MATRIX READY equal to the relay settling time.

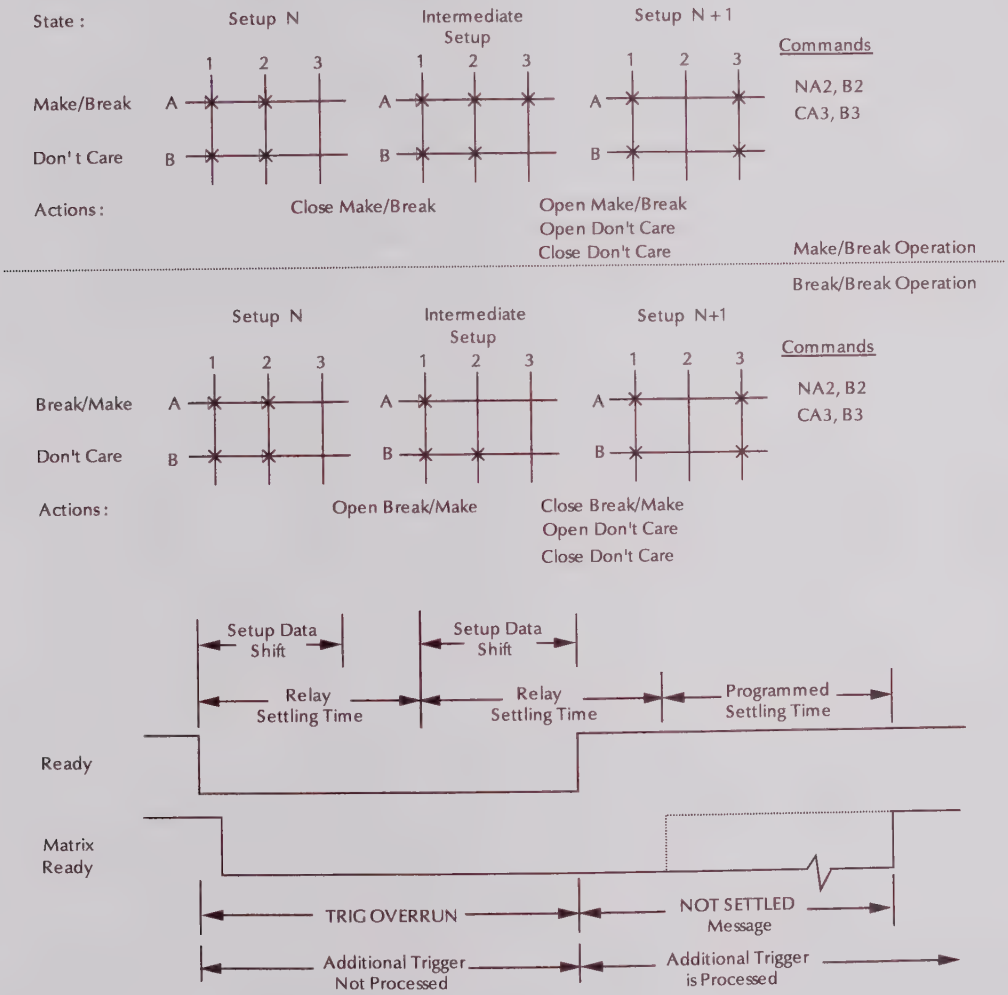


Figure 4-14
Timing with either make/break or break/make rows

When a combination of make/break and break/make rows is selected, the Model 708A must switch through three intermediate setups to ensure proper relay operation. The steps performed by the unit are:

1. Opens crosspoints in break/make rows yielding the first intermediate setup.
2. Closes crosspoints in make/break rows yielding the second intermediate setup.
3. Opens crosspoints in make/break rows yielding the third intermediate setup.
4. Closes crosspoints in break/make rows and opens/closes crosspoints in don't care rows yielding the desired setup.

Figure 4-15 shows an example setup change with the necessary intermediate setups. As the timing diagram shows, three additional relay settling time intervals are needed for the intermediate setups.

4.8.3 External trigger input

To use external triggering, first select the source as described in paragraph 4.8.1. With triggers enabled, the unit will then be triggered when an input pulse (with the specifications previously shown in Figure 4-8) is applied to the EXT TRIG INPUT jack. The unit is triggered on either the falling (leading) or rising (trailing) edge of the pulse, as selected by the A — external trigger command (paragraph 5.9.2).

4.8.4 Matrix ready output

The matrix ready output provides a TTL-compatible signal, as shown in Figure 4-9. This signal can be used to inform other instruments when the total settling time is complete. It is programmable for high or low true by the B — matrix ready command (paragraph 5.9.3). The leading edge of the true level indicates the end of the total settling time (relay settling time plus programmed settling time).

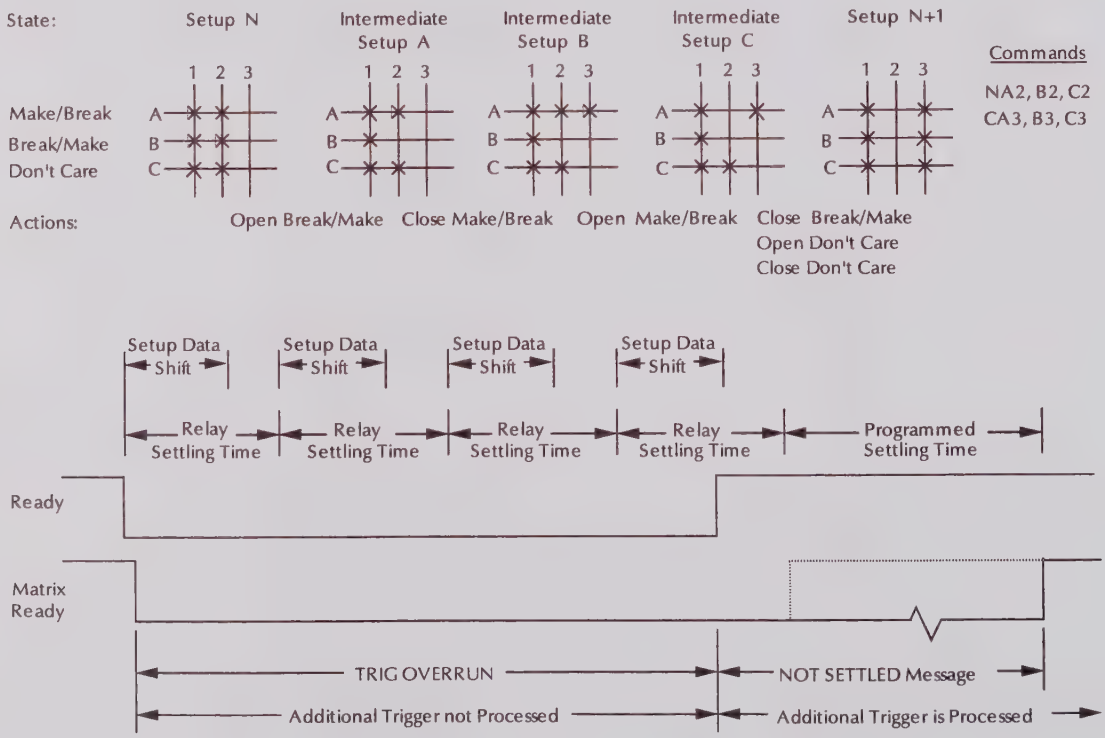


Figure 4-15
Timing with both make/break and break/make rows

4.8.5 IEEE-488 bus triggering

To trigger a setup change with an IEEE-488 trigger source, send the appropriate IEEE-488 command over the bus: X, talk, or GET depending on the selected source. Trigger on GET allows the fastest IEEE-488 triggering response. See Section 5 for details on bus triggering.

4.9 Reset

The reset operation performs the same functions as cycling power except power-up self-checking. If a master/slave error is detected during reset, the unit will revert to standalone operation. The front panel RESET key is used to initiate a reset operation.

Reset, power-up, and factory default conditions are listed in Table 4-2.

5

IEEE-488 Programming

5.1 Introduction

This section contains information on programming the Model 708A over the IEEE-488 bus. Detailed instructions for all programmable functions are included. However, information concerning operating modes presented elsewhere are not repeated.

5.2 IEEE-488 quick start

The following paragraphs provide a step-by-step procedure for putting a Model 708A on the bus to program some basic commands.

Step 1: Connect the Model 708A to the controller

With power off, connect the Model 708A to the IEEE-488 interface of the controller using a standard interface cable. Some controllers include an integral cable; others require a separate cable. Paragraph 5.3 discusses bus connections in detail.

Step 2: Select the primary address

The primary address is a way for the controller to refer to each device on the bus individually. Consequently, the primary address of your Model 708A must be the same as the primary address specified in the controller's programming language, or you cannot program the instrument. Each device on the bus must have a different primary address.

The primary address of your Model 708A is set to 18 at the factory, but you can set the address to values between 0 and 30 for a stand-alone unit, or 31 and 60 for a master in a master/slave loop (refer to paragraph 5.5).

Step 3: Write your program

All operations require a simple program to send commands to the instrument. Figure 5-1 shows a flowchart of a program to select make/break and break/make rows, modify crosspoints of a setup stored in memory, send the setup to the relays, and then request data of the present relay setup.

The corresponding program (written in MS QBASIC supplied with MS-DOS 5.0 and later) is contained in three parts for this example. The program assumes a primary IEEE-488 address of 18 for the Model 708A and that power-up default conditions exist in the unit.

Sample Program

```
DIM A$[200],C$[200]
PRINT #1, "REMOTE 18"

PRINT #1, "OUTPUT 18;V11000000W00000011X"

PRINT #1, "OUTPUT 18;E1Z1,0X"
COMMAND:
LINE INPUT "CROSSPOINTS COMMAND", C$
IF LEN (C$)=0 THEN STOP
PRINT #1, "OUTPUT 18;C$+"X"
GOTO COMMAND
END
```

Comments

```
' Dimension crosspoint input and display.
' Tell Model 708A (at IEEE-488 location 18) to
' listen over bus.
' Select rows A and B for make/break and rows
' G and H for break/make.
' Set edit pointer to setup #1, and send setup #1
' to relays and display.
' Allow user to input crosspoint data.
' Check for null string.
' Send command string to Model 708A.
' Allow user to input additional crosspoint data.
```

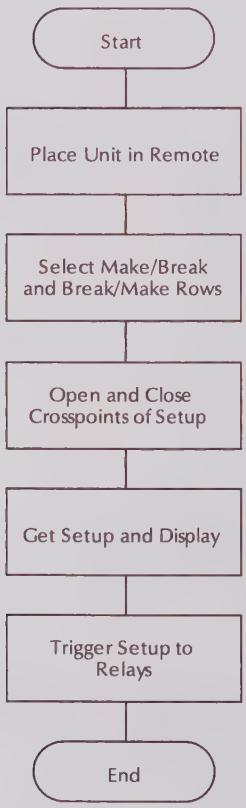


Figure 5-1
Flowchart of example program

Step 4: Open and close crosspoints

You can open, close, and clear crosspoints by sending the appropriate command, which is made up of an ASCII letter representing the command, followed by one or more characters for the command options. Commands can be grouped together in one string. The command strings are not opening and closing relays unless the edit pointer is set to zero.

To open and close crosspoints over the bus, run the previous program and enter a command string when prompted. Some example strings are shown in Table 5-1.

Terminate each string by pressing RETURN on the controller keyboard. If a null string is entered, the program ends.

Table 5-1
Sample strings

Sample string	Description
"P1"	Clear (open) all crosspoints of setup #1.
"CA5,A6,B9,B10"	Set (close) crosspoints A5, A6, B9, B10.
"NA5,A6"	Clear (open) crosspoints A5, A6.
"CA1,A2NB9,B10"	Set (close) A1, A2 and clear (open) B9, B10.

Step 5: Modify program for requesting data

To display or print setup data, you must specify one of the data output formats that sends ASCII characters. Note that a variety of data formats are available, as discussed in paragraph 5.9. The data can be a setup stored in memory or the present relay setup. Modify the previous sample program with the following statements. Add the statements immediately before the GOTO line.

```
PRINT #1, "OUTPUT 18;      ' Set data format for setup #1.
U2,1G2X"
PRINT #1, "ENTER 18"       ' Get stored setup data
LINE INPUT #2, A$          ' and print.
PRINT A$
```

When the program is run with these statements, it lists the closed crosspoints that you have entered.

Step 6: Modify program for triggering

Triggers provide a quick way for copying relay data from a pre-programmed setup to the relays. Each valid trigger causes the next sequential setup to be copied to the relays and the relay pointer to be updated.

Modify the previous sample program with the following statements. Add the statements immediately before the END line.

```
PRINT "PRESS ANY KEY TO    ' Wait for keypress.
CONTINUE"
DO
LOOP WHILE INKEY$=" "      ' Enable triggers, select
PRINT #1, "OUTPUT          ' trigger-on GET.
18;F1T2X"
PRINT #1,"TRIGGER 18"      ' Trigger setup #1 to
                           ' relays.
```

When any key on the keyboard is pressed, this program modification triggers setup #1 to the relays. This is because the relay step pointer, which is different from the edit pointer, was set to zero by power-up.

5.3 Bus cable connections

The following paragraphs provide information needed to connect instrumentation to the IEEE-488 bus. The Model 708A is connected to the IEEE-488 bus through a cable equipped with standard IEEE-488 connectors. See Figure 5-2. Two screws are located on each connector to ensure that connections remain secure. Present standards call for metric threads, as identified by dark colored screws. (Earlier versions had silver colored screws. Do not use these connectors with the Model 708A.)

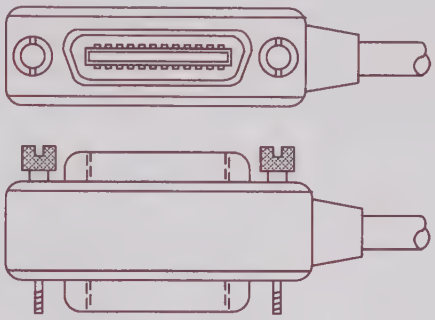


Figure 5-2
IEEE-488 connector

A typical connecting scheme is shown in Figure 5-3. Each cable normally has a standard connector on each end. These connectors are designed to be stacked to allow a number of parallel connections on one instrument. To avoid possible damage, do not stack more than three connectors on any one instrument.

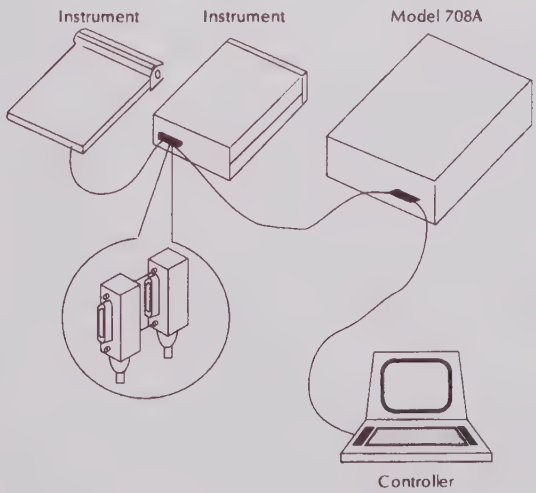


Figure 5-3
IEEE-488 connections

NOTE

To minimize interference caused by electromagnetic radiation, use only shielded IEEE-488 cables. The Model 7007-1 and 7007-2 shielded IEEE-488 cables are available from Keithley Instruments.

Connect the cable to the Model 708A as follows:

1. Line up the connector on the cable with the connector on the rear panel of the instrument. Figure 5-4 shows the IEEE-488 connector location.

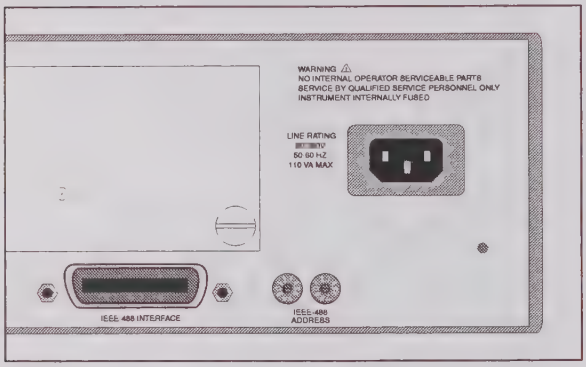


Figure 5-4
IEEE-488 connector location

2. Tighten screws securely, but do not overtighten them. (Overtightening can break the connector.)
3. Add additional connectors from other instruments, as required.
4. Make sure the other end of the cable is properly connected to the controller. Some controllers have an IEEE-488 type connector, while others do not. Consult the instruction manual of your controller for the proper connecting method.

NOTE

The IEEE-488 bus is limited to a maximum of 15 devices, including the controller. Also, the maximum cable length is limited to 20 meters, or 2 meters multiplied by the number of devices, whichever is less. Failure to observe these limits may result in erratic bus operation.

In master/slave configurations, only the master unit is connected to the IEEE-488 bus. If slave units are also connected, erratic bus operation results. Custom cables may be constructed by using the contact assignments listed in Table 5-2 and shown in Figure 5-5.

Table 5-2
Contact assignments

Number	Contact designation	IEEE-488 type
1	DIO1	Data
2	DIO2	Data
3	DIO3	Data
4	DIO4	Data
5	EOI (24)*	Management
6	DAV	Handshake
7	NRFD	Handshake
8	NDAC	Handshake
9	IFC	Management
10	SRQ	Management
11	ATN	Management
12	SHIELD	Ground
13	DIO5	Data
14	DIO6	Data
15	DIO7	Data
16	DIO8	Data
17	REN (24)*	Management
18	Gnd, (6)*	Ground
19	Gnd, (7)*	Ground
20	Gnd, (8)*	Ground
21	Gnd, (9)*	Ground
22	Gnd, (10)*	Ground
23	Gnd, (11)*	Ground
24	Gnd, LOGIC	Ground

*Number in parentheses refers to the signal ground return of reference contact number. EOI and REN signal lines return on contact 24.

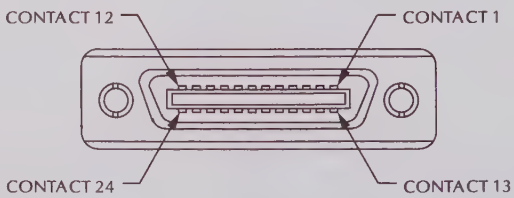


Figure 5-5
Contact assignments

5.4 Interface function codes

The interface function codes, which are part of the IEEE-488 standards, define an instrument's ability to support various interface functions. They should not be confused with programming commands found elsewhere in this manual. Interface function codes for the Model 708A are listed in Table 5-3. The codes define Model 708A capabilities as follows:

SH1 (Source Handshake) — SH1 defines the ability of the Model 708A to properly handshake data or command bytes when the unit is a source.

AH1 (Acceptor Handshake) — AH1 defines the ability of the Model 708A to properly handshake the bus when it is an acceptor of data or commands.

T6 (Talker) — The ability of the Model 708A to send data over the bus to other devices is defined by the T6 function. Model 708A talker capabilities exist only after the instrument has been addressed to talk. T6 means that the Model 708A is a basic talker, has serial poll capabilities, and is unaddressed to talk when it receives its own listen address.

TE0 (Extended Talker) — The Model 708A does not have extended talker capabilities.

L4 (Listener) — The L4 function defines the ability of the Model 708A to receive device-dependent data over the bus. Listener capabilities exist only after the instrument has been addressed to listen. L4 means that the Model 708A is a basic listener and is unaddressed to listen when it receives its own talk address.

LE0 (Extended Listener) — The Model 708A does not have extended listener capabilities.

SR1 (Service Request) — The SR1 function defines the ability of the Model 708A to request service from the controller.

RL1 (Remote Local) — The RL1 function defines the capabilities of the Model 708A to be placed in the remote or local states.

PP0 (Parallel Poll) — PP0 means that the Model 708A does not have parallel polling capabilities.

DC1 (Device Clear) — The DC1 function defines the ability of the Model 708A to be cleared (initialized).

DT1 (Device Trigger) — The ability for the Model 708A to have setups triggered is defined by the DT1 function.

C0 (Controller) — The Model 708A has no controller capabilities.

E1 (Bus Driver Type) — The Model 708A has open-collector bus drivers.

Table 5-3
Model 708A interface function codes

Code	Interface function
SH1	Source Handshake capability.
AH1	Acceptor Handshake capability.
T6	Talker (basic talker, serial poll, unaddressed to talk on MLA[1]).
TE0	No Extended Talker capabilities.
L4	Listener (basic listener, unaddressed to listen on MTA[2]).
LE0	No Extended Listener capabilities.
SR1	Service Request capability.
RL1	Remote Local capability.
PP0	No Parallel Poll capability.
DC1	Device Clear capability.
DT1	Device Trigger capability.
C0	No Controller capability.
E1	Open-collector bus drivers.

[1] MLA – My Listen Address.
[2] MTA – My Talk Address

5.5 Primary address programming

The Model 708A must receive a listen command before it responds to addressed commands. Similarly, the unit must receive a talk command before it transmits its data. The Model 708A is shipped from the factory with a primary address set at 18. The programming examples included in this manual assume the address is 18.

The primary address may be set to any value between 0 and 30 (between 30 and 60 for a master unit) as long as address conflicts with other instruments and the bus controller are avoided. Actual master unit addresses (for programming) will be 30 less than the address set on the Model 708A. Note that controllers are also given a primary address, so be sure not to use this address. Controller addresses are usually 0 or 21, but consult the controller's instruction manual for details. Make sure the primary address you choose corresponds with the value specified as part of the controller's programming language.

Two rotary switches on the rear panel of the Model 708A are used to set the IEEE-488 address. One switch is used to set each digit of the unit's address. A leading zero is required for addresses 0 through 9.

To check the present primary address, look on the rear panel of the Model 708A. If the value is above 30, the actual IEEE-488 address will be 30 less. To change the address to a new one, perform the following:

1. Power down the unit (stand-alone) or units (master/slave).
2. Change the position of the rotary switches (Figure 5-6) to the new address.

NOTE

Each device on the bus must have a unique primary address. Failure to observe this precaution could result in erratic bus operation. In a master/slave configuration, only the master Model 708A Switching Systems IEEE-488 address will be used.

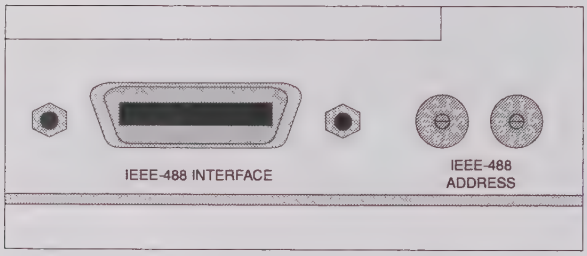


Figure 5-6
IEEE-488 bus connector and rotary selection switches

5.6 QuickBASIC programming

Programming examples are written in Microsoft QuickBASIC 4.5 using the Keithley KPC-488.2 (or Capital Equipment Corporation) IEEE interface and the HP-style Universal Language Driver (CECHP).

Before any programming example can be run, the Universal Language Driver must be installed. To install the driver, enter cechp at the DOS prompt.

If you include the CECHP command in your AUTOEXEC.BAT file, the driver will automatically be installed each time you turn on your computer.

Program fragments are used to demonstrate proper programming syntax. As the name implies, only a fragment of the whole program is used to avoid redundancy. At the beginning of each program, driver files must be opened. The input terminator should be set for CRLF. For example:

```
OPEN "ieee" FOR OUTPUT AS #1
OPEN "ieee" FOR INPUT AS #2
PRINT #1, "interm crlf"
```

A partial list of BASIC statements is shown in Table 5-4.

Table 5-4
BASIC IEEE-488 statements

Action	Basic statement
Transmit string to device 18.	`PRINT #1, "OUTPUT 18",A$`
Obtain string from device 18.	`PRINT #1, "ENTER 18"`
Read string.	`LINE INPUT #2, A$`
Display string.	`PRINT A$`
Send GTL to device 18.	`PRINT #1, "LOCAL 18"`
Send SDC to device 18.	`PRINT #1, "CLEAR 18"`
Send DCL to all devices.	`PRINT #1, "CLEAR"`
Send remote enable.	`PRINT #1, "REMOTE"`
Cancel remote enable.	`PRINT #1, "LOCAL"`
Serial poll device 18.	`PRINT #1, "SPOLL(18)"`
Send local lockout.	`PRINT #1, "LOCAL LOCKOUT"`
Send GET to device 18.	`PRINT #1, "TRIGGER 18"`
Send IFC.	`PRINT #1, "ABORT"`

5.7 Indicator and control aspects of IEEE-488 operation

The following paragraphs discuss aspects of front panel indicators and controls with respect to IEEE-488 operation, including the error LED (ERR), IEEE-488 status indicators, and the LOCAL key.

5.7.1 Error LED

The Model 708A monitors a number of operations associated with IEEE-488 programming. If an error is found, the Model 708A lights an error LED (ERR). Program the Model 708A to generate an SRQ (paragraph 5.9.12), and then the U1 error status word (paragraph 5.9.20) can be checked for specific error conditions.

The following paragraphs describe conditions (associated with IEEE-488 programming) causing the front panel ERR LED to illuminate.

Table 5-5
IEEE-488 errors causing ERR LED to illuminate

Type of error	Description
Card ID error	Power-up routine cannot identify one or more cards.
IDDC	Illegal device-dependent command received.
IDDCO	Illegal device-dependent command option received.
M/S error	Master/slave communication or timing error.
Not in remote	X received while unit is in LOCAL state.
Trigger before settling time error	Unit triggered before total settling time expired.
RAM fail	Power-up routine or self-test detected RAM error.
ROM fail	Power-up routine or self-test detected program ROM checksum error.
Setup error	Power-up routine detected checksum errors in one or more setups. (Affected setups are cleared.)
Trig overrun	Unit triggered before Ready bit is set.

Card identification error

A card ID error occurs when the instrument's power-up routine detects a checksum error in the information from a card. When in master/slave configuration, the cards in error are indicated by all LEDs in their crosspoint display blocks being lit.

IDDC (illegal device-dependent command) error

An IDDC error occurs when the unit receives an illegal device-dependent command over the bus. For example, the command string 1X includes an illegal command because the "1" is not part of the instrument's programming language.

NOTE

When an IDDC error is detected in a command string, all commands in the string, up to and including the next X, are ignored.

To correct the error condition, send only valid commands. Refer to paragraph 5.9 for device-dependent command programming details. An IDDC error is flagged in the U1 word, as discussed in paragraph 5.9.20.

IDDCO (illegal device-dependent command option) error

Sending the instrument a legal command with an illegal option results in an IDDCO error.

For example, the command K9X has an illegal option (9) that is not part of the instrument's programming language. Thus, although the command K is valid, the option is not, and the IDDCO error results.

NOTE

When an IDDCO error is detected in a command string, all commands in the string, up to and including the next X, are ignored.

To correct this error condition, use only valid command options, as discussed in paragraph 5.9. An error is flagged in the U1 word, as discussed in paragraph 5.9.20.

Master/slave error

A master/slave error occurs when a communication or timing error is detected in the closed loop of units. If one or more errors are detected, the error LED (ERR) is lit.

To simulate the error condition, disconnect a DIN cable from either of the MASTER/SLAVE connectors. The condition is detected when the Model 708A performs the next operation that requires communication among the units. A master/slave error is flagged in the U1 word, as discussed in paragraph 5.9.20.

Not in remote error

A not in remote error occurs if the instrument receives an "X" while it is in the local state. This is caused by failing to set the REN line true before addressing the Model 708A to listen. A not in remote error is flagged in the U1 word, as discussed in paragraph 5.9.20.

Trigger before settling time error

A trigger before settling time error occurs when the instrument receives an additional trigger before the settling time has expired. This time period is after assertion of the READY signal and before assertion of the MATRIX READY signal. See paragraph 4.8 for a complete discussion of trigger timing. Both READY and MATRIX READY are bits in the SPOLL byte; MATRIX READY is also a rear panel signal. Note that a master/slave error is also flagged in the U1 word, as discussed in paragraph 5.9.20.

A trigger during this time period is processed normally.

RAM or ROM failure

A RAM or ROM failure occurs when the power-up routine detects an error, either a RAM error or a checksum error in program ROM. If an error is detected, the error LED (ERR) is lit (cleared by any keypress).

Setup error

A setup error occurs when the Model 708A power-up routine detects a checksum error in one or more setups stored in non-volatile memory. If an error is detected, the error LED (ERR) is lit and the affected setups are cleared to all open. A keypress will clear this error. Note that a setup error is also flagged in the U1 word, as discussed in paragraph 5.9.20.

Trigger overrun (hardware) error

A trigger overrun occurs when the instrument is triggered while it is still processing a setup change from a previous trigger and before the READY (for trigger) signal is asserted. READY is a bit in the SPOLL byte. See paragraph 4.8 for a complete discussion of trigger timing. The exact trigger stimulus depends on the selected trigger source, as discussed in paragraphs 4.8.5 and 5.9.19.

Overrun triggers do not affect the instrument except to generate the error. In other words, the present setup change is not aborted by the overrun trigger stimulus, and the trigger is ignored. Note that a trigger overrun error is also flagged in the U1 word, as discussed in paragraph 5.9.20.

5.7.2 Status indicators

The TALK, LSTN, and REM indicators show the present IEEE-488 status of the instrument. Each of these indicators is described below.

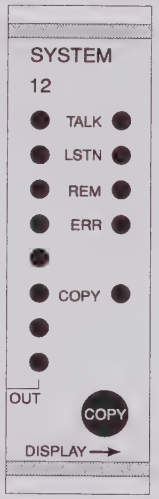


Figure 5-7
IEEE-488 indicators

TALK — This indicator is on when the instrument is in the talker active state. The unit is placed in this state by addressing it to talk with the correct MTA (My Talk Address) command. TALK is off when the unit is in the talker idle state. The instrument is placed in the talker idle state by sending it an UNT (Untalk) command, addressing it to listen, or with the IFC (Interface Clear) command.

LSTN — This indicator is on when the Model 708A is in the listener active state, which is activated by addressing the instrument to listen with the correct MLA (My Listen Address) command. Listen is off when the unit is in the listener idle state. The unit can be placed in the listener idle state by sending UNL (Unlisten), addressing it to talk, or by sending IFC (Interface Clear) over the bus.

REM — This indicator shows when the instrument is in the remote state. Note that REMOTE does not necessarily indicate the state of the REN line, as the instrument must be addressed to listen with REN true before the REMOTE indicator turns on. When the instrument is in remote, all front panel keys except for the LOCAL key are locked out. When REMOTE is turned off, the instrument is in the local state, and front panel operation is restored.

5.7.3 LOCAL/DIGITAL I/O key

This key is used to place the Model 708A in local (while the Model 708A is in remote) or in digital I/O mode (while in local). While in the digital I/O mode, an I/O will appear on the LED matrix (Figure 5-8).

LOCAL — With the Model 708A in remote, press this key to return the Model 708A Switching System to local mode (REM off). It allows operation of all other front panel controls unless the Model 708A is in LLO (Local Lockout).

DIG I/O — With the Model 708A in local, pressing this key selects the digital I/O display mode (Figure 5-8). Press this key a second time to return to local mode from digital I/O display mode.

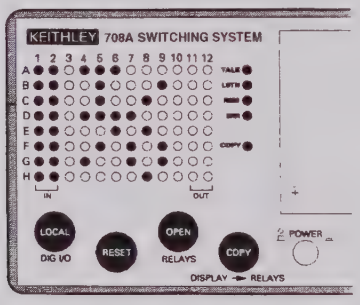


Figure 5-8
Digital I/O status display mode

IN (input) — Displays the present status of the digital input on the LED matrix. Logic high is indicated by a lit LED. The digital input display status is continually updated.

Table 5-6
Digital input display format

Row/column	Input #	Row/column	Input #
A1	1	A2	9
B1	2	B2	10
C1	3	C2	11
D1	4	D2	12
E1	5	E2	13
F1	6	F2	14
G1	7	G2	15
H1	8	H2	16

OUT (output) — Displays the present status of the digital output on the LED matrix. The output can be changed by clicking the light pen on the appropriate LED. Output high is indicated by a lit LED. Output low is indicated by an extinguished LED. The digital output display status is updated when the output is changed. Output is negative true when high LED is on and output is low (sinking).

Table 5-7
Digital output display format

Row/column	Output #	Row/column	Output #
A11	1	A12	9
B11	2	B12	10
C11	3	C12	11
D11	4	D12	12
E11	5	E12	13
F11	6	F12	14
G11	7	G12	15
H11	8	H12	16

5.7.4 Concurrent front panel and bus operation

Fundamentally, there is no reason why you cannot control the instrument simultaneously from the front panel and over the IEEE-488 bus. However, the following points should be kept in mind.

1. All front panel keys except for LOCAL are inoperative while the Model 708A is in remote (REM on). The unit is placed in remote by addressing it to listen with the REN line true. Thus, to control the unit from the front panel, it is necessary to press LOCAL after programming over the bus. Note that LOCAL is also inoperative if the LLO (Local Lockout) command is in effect.
2. Front panel parameter modification should always be completed before attempting to use bus control. For example, you should not attempt to program a setup over the bus while editing a setup from the front panel.

5.8 General bus command programming

5.8.1 Overview

General bus commands are those commands (such as DCL) that have the same general meaning regardless of the instrument. Commands supported by the Model 708A are listed in Table 5-8, which also lists BASIC statements necessary to send each command. Note that commands requiring that a primary address be specified assume that the Model 708A primary address is set to 18 (its factory default address).

5.8.2 REN (remote enable)

The remote enable command is sent to the Model 708A by the controller to set up the instrument for remote operation. Generally, the instrument should be placed in the remote state before you attempt to program it over the bus. Setting REN true does not actually place the instrument in the remote state. Instead the instrument must be addressed to listen after setting REN true before it goes into remote.

Table 5-8
General bus commands/BASIC statements

Command	Basic statement	Effect on Model 708A
REN	`PRINT #1, "REMOTE"`	Goes into effect when next addressed to listen.
IFC	`PRINT #1, "ABORT"`	Goes into talker and listener idle states.
LLO	`PRINT #1, "LOCAL LOCKOUT"`	LOCAL key locked out.
GTL	`PRINT #1, "LOCAL 18"`	Cancel remote, restore front panel operation.
DCL	`PRINT #1, "CLEAR"`	Return to default conditions.
SDC	`PRINT #1, "CLEAR 18"`	Return to default conditions.
GET	`PRINT #1, "TRIGGER 18"`	Triggers setup with GET source.

NOTE

The instrument need not be in remote to be a talker. All front panel controls (except LOCAL and POWER) are inoperative while the instrument is in remote. You can restore normal front panel operation by pressing the LOCAL key.

5.8.3 IFC (interface clear)

The IFC command is sent by the controller to place the Model 708A in the local, talker, and listener idle states. The unit responds to the IFC command by canceling front panel TALK or LSTN lights, if the instrument was previously placed in one of those states.

5.8.4 LLO (local lockout)

The LLO command is used to prevent local operation of the instrument. After the unit receives LLO, all of its front panel controls except POWER are inoperative.

5.8.5 GTL (go to local)

The GTL command is used to take the instrument out of the remote state. Operation of the front panel keys will also be restored by GTL unless LLO is in effect. To cancel LLO, you must set REN false.

5.8.6 DCL (device clear)

The DCL command may be used to clear the Model 708A and return it to its power-up default conditions (see Table 4-2). Note that the DCL command is not an addressed command, so all instruments equipped to implement DCL will do so simultaneously. When the Model 708A receives a DCL command, it returns to the power-up default conditions. DCL does not affect the programmed primary address.

5.8.7 SDC (selective device clear)

The SDC command is an addressed command that performs essentially the same function as the DCL command. However since each device must be individually addressed, the SDC command provides a method to clear only selected instruments instead of clearing all instruments simultaneously, as is the case with DCL. Any devices on the bus that are addressed to listen are cleared. When the Model 708A receives the SDC command, it returns to the power-up default conditions.

5.8.8 GET (group execute trigger)

GET may be used to initiate a Model 708A setup change if the instrument is placed in the appropriate trigger source. Refer to paragraph 5.9 for more information on triggering.

5.8.9 SPE, SPD (serial polling)

The serial polling sequence is used to obtain the Model 708A serial poll byte. The serial poll byte contains important information about internal functions, as described in paragraph 5.9.12. Generally, the serial polling sequence is used by the controller to determine which of several instruments has requested service with the SRQ line. However, the serial polling sequence may be performed at any time to obtain the serial poll byte from the Model 708A.

Table 5-9
Factory default, power-up, and DCL/SDC conditions

Parameter	Factory default	Power-up, DCL/SDC	Description
Relays	All opened	All opened	—
Stored Setups	All cleared	Not affected	—
Relay Step	000	000	Point to relays
Memory Step	001	001	Point to setup 1
Master/Slave	Stand-alone	(Notes 2, 3)	—
IEEE-488 Address	18 (Note 1)	Not affected	—
External Trigger	A0	A0	Falling edge triggers
Matrix Ready	B0	B0	Negative true
Digital Output	Db, 0	Db, 0	Output lines low
Edit Pointer	E0	E0	Point to relays
Trigger Enable	F0	F0	Triggers disabled
Data Format	G0	G0	Full output, all data sent in one talk
EOI/Hold-off	K0	K0	Both enabled
SRQ	M0	M0	Disabled
Digital Output	O00000	O00000	Output lines low
Programmed Settling Time	S0	S0	0ms
Trigger Source	T7	T7	External trigger
Make/Break Rows	V00000000	Not affected	None selected
Break/Make Rows	W00000000	Not affected	None selected
Terminator	Y0	Y0	<CR><LF>

Notes:
1. The IEEE-488 address is not affected by the Restore (R0) command.
2. Units previously defined as stand-alone or slave will power up as stand-alone units. They become slave units when a master unit initializes a master/slave loop upon power up.
3. DCL/SDC does not affect master/slave state. DCL/SDC does clear slaves.

5.9 Device-dependent command (DDC) programming

5.9.1 Overview

IEEE-488 device-dependent commands control most instrument operating modes. All front panel modes (such as trigger source and settling time), as well as some modes not available from the front panel (like SRQ and terminator) can be programmed with these commands.

Command syntax

Each command is made up of a single ASCII capital letter followed by one or more numbers or letters representing an option(s) of that command. For example, the trigger source can be set over the bus by sending the letter "T" followed by a number representing the trigger option. T1X would be sent to trigger on talk. The IEEE-488 bus treats these commands as data; they are sent with the ATN line false.

Some commands permit more than one option; these must be separated with commas. For example, the close crosspoints commands have the general format:

Crc(,rc)...(,rc)

Here the "rc" options are row and column addresses, while the commas indicate the necessary delimiters. The parentheses indicate that the option and associated delimiter are optional.

NOTE

Do not include parentheses in actual command strings.

Multiple commands

A number of commands can be grouped together in one command string, which is generally terminated by the "X" character. This character tells the instrument to execute the command or command string as described in paragraph 5.9.23. Commands sent without the X character are not exe-

cuted at that particular time, but they are stored within an internal command buffer for later execution when the X character is finally received.

If a particular command occurs "n" times in a command string, then the "nth" occurrence is the only one used (i.e., T0T2T4X appears to the Model 708A as T4X).

Invalid commands

If an invalid command is sent as part of the command string, no commands in the string are executed. Under these conditions, the instrument displays a front panel error message (IDDC or IDDCO), as described in paragraph 5.7, and it can be programmed to generate an SRQ (Service Request), as discussed in paragraph 5.9.12. Checking is done as syntactical groups of characters are received.

Valid command strings (typical samples)

`A0X`	Single command string.
`A0T6X`	Multiple command string.
`P 0X`	Space is ignored
`Z15,0X`	Multiple-option command string (options separated by commas).

Invalid command strings (typical samples)

`1X`	Invalid command as 1 is not a valid command.
`K7X`	Invalid command option as 7 is not a valid option of the K command.
`CA400X`	Invalid option (maximum column address is 60).
`Z0100X`	Multiple-option command without the necessary separating commas.

Order of command execution

Device-dependent commands are not necessarily executed in the order received. Rather, each instrument always executes them in a specific order. The order of execution for the Model 708A is summarized in Table 5-10. Note that the X command is listed first since it is the character that forces the execution of the rest of the commands.

If you wish to force a particular order of execution, include the execute (X) character after each command option grouping in the command string. For example, the following string would be executed in the received order: T6XA1XR0X

Table 5-10
Order of command execution

Order	Command	Description
1	X	Execute DDCs.
2	R	Restore factory default conditions.
3	L	Download setups from controller to Model 708A.
4	E	Set the edit pointer.
5	I	Insert a blank setup in memory.
6	Q	Delete a setup from memory.
7	P	Clear all crosspoints at specified setup.
8	Z	Copy a setup from memory or relays to memory or relays.
9	V	Select rows for make/break.
10	W	Select rows for break/make.
11	N	Open crosspoints of setup indicated by edit pointer.
12	C	Close crosspoints of setup indicated by edit pointer.
13	A	Select trigger edge of External Trigger pulse.
14	B	Select logic sense of Matrix Ready signal.
15	F	Enable/disable triggers.
16	G	Select data output format.
17	J	Execute ROM/RAM/display self-test.
18	K	Select EOI and hold-off on X.
19	M	Set the SRQ mask.
20	O	Set the digital output.
21	S	Program the settling time.
22	T	Select the trigger source.
23	U	Request status.
24	Y	Select terminator characters.

Device-dependent command summary

All Model 708A device-dependent commands are summarized in Table 5-11, which also lists respective paragraphs where more detailed information on each command may be found.

Table 5-11
DDC summary

Mode	Command	Description	Para.
External Trigger	A0	Falling edge triggers Model 708A	5.9.2
	A1	Rising edge triggers Model 708A	5.9.3
Matrix Ready	B0	Negative true Matrix Ready output	
	B1	Positive true Matrix Ready output	
Close Crosspoint	Crc(,rc)...(,rc)	Close crosspoints of setup indicated by edit pointer (rows A-H, columns 1-60)	5.9.4
Digital Output	Db, s	Set states of digital output lines (b = 1 to 16, s = 0 to 1)	5.9.5
Edit Pointer	E0	Point to present relay setup	5.9.6
	En	Point to stored relay setup (1-100)	
Enable/Disable Triggers	F0	Disable triggers	5.9.7
	F1	Enable triggers	
Data Format	G0	Full output, all data in one talk	5.9.8
	G1	Full output, one switching system row per talk	
	G2 or G3	Inspect output, all data in one talk	
	G4	Condensed output, all data in one talk	
	G5	Condensed output, one switching system per talk	
	G6	Binary output, all data in one talk	
	G7	Binary output, one switching system per talk	
Insert Blank Setup	In	Insert blank setup in memory (1-100)	5.9.9
Self-test	J0	Perform self-test	5.9.10
EOI and Hold-off	K0	Send EOI, hold-off on X until Ready	5.9.11
	K1	No EOI, hold-off on X until Ready	
	K2	Send EOI, do not hold-off on X	
	K3	No EOI, do not hold-off on X	
	K4	Send EOI, hold-off on X until Matrix Ready	
	K5	No EOI, hold-off on X until Matrix Ready	
Download Setups	Lbbb..X	Download setups from controller to Model 708A	5.9.12
SRQ	M0	SRQ disabled	5.9.13
	M1	Not used	
	M2	Not used	
	M8	Matrix Ready	
	M16	Ready for trigger	
	M32	Error	
	M128	Not used	
Open Crosspoint	Nrc(,rc)...(,rc)	Open crosspoints of setup indicated by edit pointer (rows A-H, columns 1-60)	5.9.14
Digital Output	Ovvvvv	Set states of digital output lines (v = 00000-65535)	5.9.15
Clear Crosspoints	P0	Open all crosspoint relays	5.9.16
	Pn	Clear all crosspoints of stored setup (1-100)	
Delete Setup	Qn	Delete setup from memory (1-100)	5.9.17
Restore Defaults	R0	Restore factory defaults	5.9.18
Programmed Settling Time	Sn	Program settling time in milliseconds (0-65000)	5.9.19
Trigger	T0 or T1	Trigger on talk	5.9.20
	T2 or T3	Trigger on GET	
	T4 or T5	Trigger on X	
	T6 or T7	Trigger on External Trigger pulse	

Table 5-11 (cont.)
DDC summary

Mode	Command	Description	Para.
Status	U0	Send machine status word	5.9.21
	U1	Send error status word	
	U2,s	Output setup "s" (0-100) with present G format	
	U3	Send RELAY STEP pointer	
	U4	Send number of slaves	
	U5,u	Send model number of each card in unit "u" (0-4)	
	U6	Send relay settling time	
	U7	Send digital input of unit (0-65535)	
Make/Break	Vabcdefgh	Select rows for make/break operation (abcdefgh = 00000000 to 11111111)	5.9.22
Break/Make	Wabcdefgh	Select rows for break/make operation (abcdefgh = 00000000 to 11111111)	5.9.23
Execute	X	Execute commands	5.9.24
Terminator	Y0	<CR><LF>	5.9.25
	Y1	<LF><CR>	
	Y2	<CR>	
	Y3	<LF>	
Copy Setup	Z0,n	Copy present relay setup to memory location "n" (1-100)	5.9.26
	Zn,0	Copy setup from memory location "n" (1-100) to relays	
	Zm,n	Copy setup from location "m" (0-100) to location "n" (0-100)	

5.9.2 A — External trigger

Purpose To select which edge of an external trigger pulse initiates a trigger.

Format An

Parameters
n=0 Falling edge triggers Model 708A
n =1 Rising edge triggers Model 708A

Default Upon power-up or after receiving a DCL, SDC, or R0X command, the instrument defaults to A0 (falling edge).

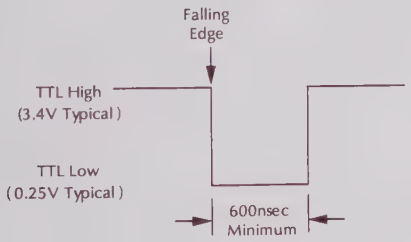
Description The An command lets you program the Model 708A for triggering on a TTL-compatible falling or rising edge signal at the External Trigger input jack. A trigger signal increments the RELAY STEP pointer and copies the setup indicated by the new value from memory to the relays.

Figure 5-9 shows example trigger pulses. Trigger on external must be the selected source (T command), and triggers must be enabled (F command).

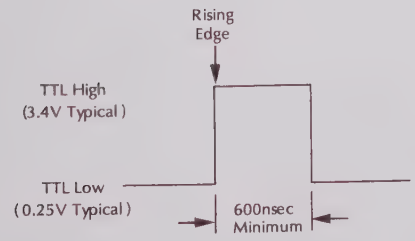
Programming note For information on the hardware this command is used with, refer to paragraph 4.6.2.

Example

```
PRINT #1, "OUTPUT 18;A1X"        ' Select rising edge pulse to trigger
PRINT #1, "OUTPUT 18;A0X"        ' Select falling edge to trigger
```



A. FALLING EDGE OF PULSE



B. RISING EDGE OF PULSE

Figure 5-9
External trigger pulse

5.9.3 B — Matrix ready

Purpose To select the logic sense of the rear panel Matrix Ready signal.

Format Bn

Parameters
n=0 Negative true Matrix Ready output
n=1 Positive true Matrix Ready output

Default Upon power-up or after receiving a DCL, SDC, or R0X command, the instrument defaults to B0 (negative true).

Description The B command lets you program the TTL-compatible Matrix Ready output as a high- or low-true signal. This signal goes false when the relays are switched; it goes true after completion of the (hardware) relay settling time and (user) programmed settling time. Figure 5-10 shows example Matrix Ready signals.

Programming notes
1. The Matrix Ready signal is negated by anything that causes a change to a relay state even if no relays actually change state (e.g., closing an already closed relay).
2. Changing the logic sense of the Matrix Ready signal does not change the logic sense of the Matrix Ready bit in the serial poll byte.

Example

```
PRINT #1, "OUTPUT 18;B1X"          ' Select positive true Matrix Ready
PRINT #1, "OUTPUT 18;B0X"          ' Select negative true Matrix Ready
```

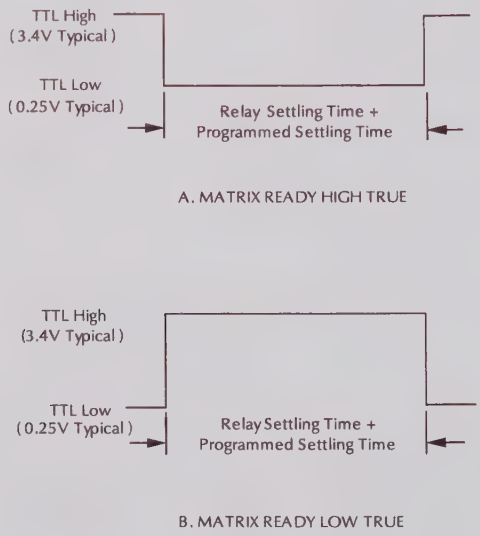


Figure 5-10
Matrix ready pulse

5.9.4 C — Close crosspoint

Purpose To close crosspoints in a setup.

Format Crc(,rc)...(,rc)

Parameters
r = A to H Row designation of crosspoint
c = 1 to 60 Column designation of crosspoint (60 with maximum of five Model 708A units)

Description The C command closes crosspoints in the setup indicated by the edit pointer. If the edit pointer indicates the present relay setup (zero), the specified crosspoint relays are closed immediately. If the edit pointer indicates a setup stored in memory (1-100), the specified crosspoints are set.

Programming notes
1. Do not include parentheses in command strings. They indicate that the option and associated comma delimiter are optional.
2. Up to 25 crosspoints per mainframe can be specified in one close command (with a master and four slaves, the limit is 125 crosspoints). In the same command string, up to 25 crosspoints per mainframe can be opened. If either limit is exceeded, an IDDCO results.
3. The maximum value of the column parameter depends on the configuration (12 for standalone, 60 for master with four slave units). An IDDCO results if the maximum value is exceeded.
4. This command is equivalent to multiple light pen operation(s).

Example
```
PRINT #1, "OUTPUT 18;CA55X"                    ' Close one crosspoint
PRINT #1, "OUTPUT 18;CA55,A56,B49,B50X"        ' Close multiple crosspoints
```

5.9.5 D — Digital output

Purpose To set the states of the digital output lines.

Format Db,s

Parameters
b = 1 to 16 Output bit position
s = 0 to 1 0 = off, 1 = on

Default Upon power-up or after receiving a DCL, SDC, or R0X command, the instrument defaults to D0,0 (all digital outputs set to logic low).

Description This command sets individual output lines of the digital I/O port, where "1" is logic high and "0" is logic low.

Programming notes
1. In a master/slave configuration, only the output of the master unit is updated.
2. Output is negative true logic. Setting a bit high will make an output go low (sink).
3. The O command can also be used to set the states of digital output lines.

Example
```
PRINT #1, "OUTPUT 18;D3,1X"          'Turn on digital output 3
```

5.9.6 E — Edit pointer

Purpose To set the edit pointer

Format En

Parameters

n=0	Present relay setup
n=1 to 100	Stored relay setup

Default Upon power-up or after receiving a DCL, SDC, or R0X command, the instrument defaults to E0 (present relay setup).

Description With the edit pointer, you can select which setup is affected by subsequent close (C) and open (N) commands. This can be the present relay setup (zero) or one of the stored setups (1-100).

Programming notes

1. The edit pointer value is independent of the Relay Step and Memory Step values.
2. When using the edit pointer, it is not necessary to use the COPY key, because you are closing/opening crosspoint relays or setting/clearing stored crosspoints directly and not just turning on/off crosspoint LEDs.

Example

```
PRINT #1, "OUTPUT 18;E0X"          ' Point to relays
PRINT #1, "OUTPUT 18;E50X"         ' Point to stored relay setup 50
```

5.9.7 F — Enable/disable triggers

Purpose To enable/disable triggers.

Format Fn

Parameters

n=0	Disable triggers
n=1	Enable triggers

Default Upon power-up or after receiving a DCL, SDC, or R0X command, the instrument defaults to F0 (triggers disabled).

Description With the F command, you control whether the Model 708A responds to a trigger (from the external trigger connection or over the IEEE-488 bus). A trigger increments the Relay Step pointer and copies the setup indicated by the new value from memory to the relays.

Programming notes It is good programming practice to disable triggers before changing the trigger source.

Example

```
PRINT #1, "OUTPUT 18;F0X"          ' Enable triggers
•
•
•
PRINT #1, "OUTPUT 18;F1X"          ' Disable triggers
```

5.9.8 G — Data format

Purpose

To select the output format of the data sent from the present relay setup or a setup stored in memory.

Format

Gn

Parameters

n=0	Full output format, all data sent in one talk
n=1	Full output format, one row of one switching system per talk
n=2 or 3	Inspect output format, all data sent in one talk
n=4	Condensed output format, all data sent in one talk
n=5	Condensed output format, one switching system per talk
n=6	Binary output format, all data sent in one talk
n=7	Binary output format, one switching system per talk

Default

Upon power-up or after receiving a DCL, SDC, or R0X command, the instrument defaults to G0 (full output format, all data sent in one talk).

Description

Overview

The G command specifies the format of crosspoint data sent by the Model 708A over the IEEE-488 bus in response to the U2 command. Data concerning the setup is sent by a "U2,n" command (either the present relay setup or a stored setup). You can control the data format and quantity sent. The full, condensed, and binary formats list the open or closed states of every crosspoint in the setup; the inspect format shows only closed crosspoints.

G0, G1 = Full output format

With the G0/G1 full output formats, the open or closed states of all crosspoints in a setup are sent in printable ASCII. An ASCII "-" represents an open crosspoint, and an ASCII "X" represents a closed crosspoint. For G0, all data is sent in one talk; for G1, the data from one row of one switching system is sent per talk. An example of these formats is shown in Figure 5-11 for the example setup of Table 5-12.

G2, G3 = Inspect output format

With the G2/G3 inspect output formats, the row/column address of each closed crosspoint in a setup is sent in printable ASCII. An ASCII letter (A-H) represents a row, and an ASCII string of up to two numbers (0-60) represents a column. Successive crosspoints are separated with a comma. All data is sent in one talk. Figure 5-12 shows the formats of the example setup in Table 5-12.

G4, G5 = Condensed output format

The G4/G5 condensed output formats specify the states of all crosspoints with eight bits representing the eight crosspoints of a column. A set bit indicates a closed crosspoint. The hexadecimal representation of the binary value formed by these eight bits is sent as two printable ASCII characters. For G4, all data is sent in one talk; for G5, the data from one switching system is sent per talk. An example of these formats is shown in Figure 5-13 for the example setup of Table 5-12.

G6, G7 = Binary output format

The G6/G7 binary output formats specify the states of all crosspoints with an 8-bit group of bits representing the eight crosspoints of a column. A set bit indicates a closed crosspoint. For G6,

all data is sent in one talk; for G7, the data from one switching system is sent per talk. These formats are shown in Figure 5-14 for the example setup of Table 5-12.

Table 5-12
Master/slave setup example

Unit	Closed crosspoints
Master	A1, A2, B3, B5, C7, C8, D9, D10, F11, F12
Slave 1	A13, A14, C15, C16, E17, E18
Slave 2	A25, A26, H27, H30, A36
Slave 3	A37, H38, H43, G48
Slave 4	G49, A50, A51, H55, H56, E57, E60

Obtaining data

Generally, data is placed into a string or numeric variable. For example, a typical input sequence in BASIC is:

```
PRINT #1, "ENTER 18"
LINE INPUT #2, CROSSPOINT$
```

In this example, the complete crosspoint string is placed in the CROSSPOINT$ variable.

Programming notes

1. Table 5-13 lists the number of bytes that are transmitted for the various data formats.
2. Since the data is transmitted in continuous strings (without carriage returns or line feeds), you must format the data for display or printing legibility.

Table 5-13
Byte counts for data format

Format	Stand-alone			Master with four slaves		
	Bytes per talk	Talks per setup	Total bytes	Bytes per talk	Talks per setup	Total bytes
G0	121	1	121	605	1	605
G1	14 (Note 1)	9	121	14 (Note 1)	45	605
G2	(Note 2)	1	(Note 2)	(Note 2)	1	(Note 2)
G3	(Note 2)	1	(Note 2)	(Note 2)	1	(Note 2)
G4	32	1	32	160	1	160
G5	32	1	32	32	5 (Note 3)	160
G6	16	1	16	80	1	80
G7	16	1	16	16	5 (Note 3)	80

Notes:
1. In addition, each unit is identified with a 9-byte ASCII string.
2. This value depends on the number of closed crosspoints.
3. Maximum of five talks, depending on number of slaves in the system.

```
SETUP 003          SLAVE 001          SLAVE 002          SLAVE 003          SLAVE 004
A  XX----------    A  XX----------    A  -XX---------    A  XX----------    A  --XX--------
B  --X-X-------    B  ------------    B  ------------    B  ------------    B  ------------
C  -------XX----    C  --XX--------    C  ------------    C  ------------    C  ------------
D  --------XX--    D  ------------    D  ------------    D  ------------    D  ------------
E  ------------    E  -----XX-----    E  ------------    E  ------------    E  ------------
F  ----------XX    F  ------------    F  ------------    F  ------------    F  ------------
G  ------------    G  ------------    G  ------------    G  ------------    G  XX----------
H  ------------    H  ------------    H  ---X--X-----    H  --X----X----    H  ------XXX---
```

Notes:
1. Carriage returns and line feeds are not sent. They are shown here to improve readability.
2. Spacing between columns is one ASCII space.

Figure 5-11
G0 and G1 full output formats

A001,A002,B003,B005,C007,C008,D009,D010,F011,F012,A013,A014,C015,C016,E017,E018,A025,
A026,H027,H030,A036,A037,H038,H043,G048,G049,A050,A051,H055,H056,E057,E060

Note: Carriage returns and line feeds are not sent. They are shown here to improve readability.

Figure 5-12
G2 and G3 inspect output formats

MASTER	0003 00	*SETUP NUMBER (2 BYTES), UNIT NUMBER (1 BYTE)*
	0101020002000404080820 20	*CARD COLUMN 1–12*
	XX	*CHECKSUM*
SLAVE 1	0003 01	
	0101040410100000000000 00	
	XX	
SLAVE 2	0003 02	
	0001018000008000000000 00	
	XX	
SLAVE 3	0003 03	
	0100800000000080000000 00	
	XX	
SLAVE 4	0003 04	
	4040010100008080800000 00	
	XX	

Notes:
1. Data is shown as the hexadecimal representation of 8-bit binary numbers (Figure 5-15).
2. Carriage returns, line feeds, spaces, and blank lines are not sent. They are shown here to improve readability.
3. "XX" represents a 1-byte checksum value (hexadecimal) in printable ASCII.
4. The rows that correspond to the G4/G5 data are:

G4/G5 Data	Corresponding row
00	None
01	A
02	B
04	C
08	D
10	E
20	F
40	G
80	H

Figure 5-13
G4 and G5 condensed output formats

	SETUP NUMBER 2 BYTES		UNIT NUMBER 1 BYTE			ROW H ROW A	
MASTER	00000000	00000011	00000000				
	00000001	00000001	00000010	00000000	00000010	00000000	*COLUMNS 1-6*
	00000100	00000100	00001000	00001000	00100000	00100000	*COLUMNS 7-12*
	XXXXXXXX						*CHECKSUM (1 BYTE)*
SLAVE 1	00000000	00000011	00000001				
	00000001	00000001	00000100	00000100	00000000	00010000	
	00010000	00000000	00000000	00000000	00000000	00000000	
	XXXXXXXX						
SLAVE 2	00000000	00000011	00000002				
	00000000	00000001	00000001	10000000	00000000	00000000	
	10000000	00000000	00000000	00000000	00000000	00000000	
	XXXXXXXX						
SLAVE 3	00000000	00000011	00000003				
	00000001	00000001	10000000	00000000	00000000	00000000	
	00000000	10000000	00000000	00000000	00000000	00000000	
	XXXXXXXX						
SLAVE 4	00000000	00000011	00000004				
	01000000	01000000	00000001	00000001	00000000	00000000	
	10000000	10000000	10000000	00000000	00000000	00000000	
	XXXXXXXX						

Notes:
1. Row A corresponds to the least significant bit of each 8-bit groups; Row H corresponds to the most significant bit.
2. Data is shown as the binary representation of 8-bit binary numbers. The binary value sent may not correspond to a printable ASCII character.
3. Carriage returns, line feeds, spaces, and blank lines are not sent. They are shown here to improve readability.
4. Represents an 8-bit checksum value in binary.

Figure 5-14
G6 and G7 binary output formats

5.9.9 I — Insert blank setup

Purpose To insert a blank setup in memory.

Format In

Parameters n=1 to 100 Stored relay setup

Description During execution of this command, setups "n" through 99 are shifted up to the next highest location in memory (99 to 100, 98 to 99... n to n+1). Then, all crosspoints of setup "n" are cleared. The front panel display is blanked during an insert operation.

Example

```
PRINT #1, "OUTPUT 18;I50"          ' Insert blank setup at location 50
```

5.9.10 J — Self-test

Purpose To test ROM and RAM.

Format Jn

Parameters n=0 Perform self-test

Description The self-test command starts execution of the ROM and RAM. If an error is detected, the error LED (ERR) lights. Also, the self-test failed bit is set in the U1 error status word (paragraph 5.9.20). Any front panel keypress or bus command extinguishes the error LED.

Programming notes

1. The value "n", if sent, must be zero.
2. Allow approximately four seconds for the instrument to complete the self-test.
3. The instrument holds off bus operation with the NRFD line during self-test operation. Thus, no commands can be sent during the self-test if hold-off on X is enabled.

Example

```
PRINT #1, "OUTPUT 18;J0X"          ' Perform self-test
```

5.9.11 K — EOI and hold-off

Purpose To enable/disable EOI and bus hold-off on X.

Format Kn

Parameters

n = 0 Send EOI with last byte, hold-off on X until Ready
n = 1 No EOI, hold-off on X until Ready
n = 2 Send EOI with last byte, do not hold-off on X
n = 3 No EOI, do not hold-off on X
n = 4 Send EOI with last byte, hold-off on X until Matrix Ready
n = 5 No EOI, hold-off on X until Matrix Ready

Default Upon power-up or after receiving a DCL, SDC, or R0X command, the instrument defaults to K0 (send EOI with last byte, hold-off on X until Ready).

Description

The EOI line provides one method to positively identify the last byte in the data string sent by the instrument. When enabled, EOI is asserted with the last byte the instrument sends over the bus.

Bus hold-off allows the instrument to temporarily hold up bus operation via the NRFD line when it receives the X character until all commands are processed. The advantage of using bus hold-off is that no commands are missed while the instrument is processing previously received commands. Typical hold-off times are discussed in paragraph 5.11.

Programming notes

1. Some controllers rely on EOI to terminate their input sequences. Suppressing EOI may cause the controller input sequence to hang.
2. When reading a buffer, EOI is asserted only at the end of the entire buffer transmission.
3. When enabled, EOI is asserted with the last byte in the terminator.
4. When bus hold-off is enabled, all bus activity is held up for the duration of the hold-off period, not just for the duration of the communication with the Model 708A.

Example

```
PRINT #1, "OUTPUT 18;K1X"          ' No EOI, hold-off on X until Ready
PRINT #1, "OUTPUT 18;K2X"          ' Send EOI with last byte, do not hold-off on X
```

5.9.12 L — Download setups

Purpose

To download setups from the controller to the Model 708A.

Format

Lbbbb...X

Parameters

bbbb... represents the G4/G5 or G6/G7 output string.

Description

This command downloads setup information in a G4/G5 or G6/G7 data format. It is used in conjunction with the U2 command (output setup data) to back up or expand the setups stored in the Model 708A.

G formats are discussed in paragraph 5.9.7; see paragraph 5.9.20 for U commands.

Programming notes

1. The data format for downloading is specified by the G format presently in effect.
2. The setup data string begins with a setup number and unit number and ends with a checksum value.
3. The setup number is specified in a U2,n command (output setup "n"), as shown in the following programming example.

Example

```
DIM SETUP$[32]                     ' Dimension for stand-alone
PRINT #1, "REMOTE 18"              ' Setup #1 in G4 format
PRINT #1, "OUTPUT 18;G4U2,1X"      ' Get setup data
PRINT #1, "ENTER 18"
LINE INPUT #2, SETUP$
PRINT SETUP$[1,6]                  ' Print setup and unit numbers
PRINT SETUP$[7,30]                 ' Print setup data card by card
PRINT SETUP$[31,32]                ' Print checksum
PRINT "PRESS ANY KEY TO CONTINUE"  ' Inspect setup data
DO
LOOP WHILE INKEY$= " "             ' Wait for keypress
PRINT #1,"OUTPUT 18;"L"+SETUP$+"X""  ' Download setup back to 708A
```

5.9.13 M — SRQ and serial poll byte

Purpose To program which conditions generate an SRQ (service request).

Format Mn

Parameters

n=0 SRQ disabled
n=1 Not used
n=2 Not used
n=4 Not used
n=8 Matrix Ready
n=16 Ready for trigger
n=32 Error
n=128 Not used

Default Upon power-up or after receiving a DCL, SDC, or R0X command, the instrument defaults to M0 (SRQ disabled).

Description The SRQ command selects which conditions cause the Model 708A to generate an SRQ (service request). Once an SRQ is generated, the serial poll byte can be checked to determine if the Model 708A was the instrument that generated the SRQ, and, if so, what conditions caused it.

The general format of the SRQ mask used to generate SRQs is shown in Figure 5-15. By sending the appropriate M command, you can set the appropriate bit(s) to enable SRQ generation if those particular conditions occur. Possible conditions are:

- The Matrix Ready signal has been asserted (M8).
- The Ready (for trigger) signal has been asserted (M16).
- An error has occurred (M32). The nature of the error can be determined by reading the U1 error word as described in paragraph 5.9.20.

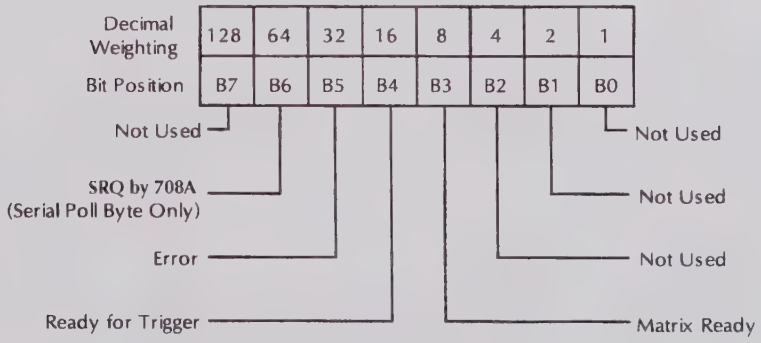


Figure 5-15
SRQ mask and serial poll byte format

Serial poll byte

The general format of the serial poll byte is shown in Figure 5-15. Note that all bits except for bit 6 correspond to the bits in the SRQ mask. These bits flag the following conditions:

Matrix ready (bit 3) — Set whenever the Matrix Ready signal is asserted. Cleared by the start of relay switching.

Ready for trigger (bit 4) — Set when the Ready signal is asserted. This bit is cleared by:

1. Receipt of X. Start of relay switching.
2. Front panel keypress on master unit.
3. Changing Make/Break or Break/Make row.
4. Performing self-test.

Error (bit 5) — Set if an error condition occurs. Cleared by reading the U1 error status word (paragraph 5.9.20).

SRQ (bit 6) — Set if the Model 708A requests service via the SRQ line; cleared by a serial poll.

Programming notes

1. The serial poll byte should be read once the instrument has generated an SRQ to clear the SRQ line.
2. All bits in the serial poll byte latch when the instrument generates an SRQ.
3. If an error occurs, bit 5 (error) in the serial poll byte latches and remains so until the U1 word is read (paragraph 5.9.20).
4. Multiple error conditions can be programmed by adding up the individual command values. For example, send M12X for SRQ under matrix ready and digital I/O interrupt conditions.

Example

```
PRINT #1, "CLEAR 18"
PRINT #1, "REMOTE 18"                    ' Program for SRQ on error
PRINT #1, "OUTPUT 18;M32X"               ' Attempt to program invalid option
PRINT #1, "OUTPUT 18;A2X"                ' Check interface status

WAITSRQ:
IF NOT(srq%()) THEN GOTO WAIT SRQ        ' Wait for SRQ to occur
PRINT #1, "SPOLL 18"                     ' Serial poll the instrument
INPUT #2, S                              ' Read serial poll byte
PRINT "B7 B6 B5 B4 B3 B2 B1 B0"          ' Label the bit positions
FOR I=7 TO 0 STEP-1                      ' Loop eight times
PRINT BIT (S,I);                         ' Display the bit positions
NEXT I
PRINT
PRINT #1, "OUTPUT 18;U1X"                ' Program for error status
PRINT #1, "ENTER 18"                     ' Get U1 status to clear error
LINE INPUT #2, ERROR$
PRINT ERROR$                             ' Display error status
```

5.9.14 N — Open crosspoint

Purpose To open crosspoints in a setup.

Format Nrc(,rc)...(,rc)

Parameters

r=A to H	Row designation of crosspoint
c=1 to 60	Column designation of crosspoint (60 with maximum of five Model 708A units)

Description The N command opens crosspoints in the setup indicated by the edit pointer. If the edit pointer indicates the present relay setup (zero), the specified crosspoint relays are opened immediately. If the edit pointer indicates a setup stored in memory (1-100), the specified crosspoints are cleared.

Programming notes

1. Do not include parentheses in command strings. They indicate that the option and associated comma delimiter are optional.
2. Up to 25 crosspoints per mainframe can be specified in one open command (with a master and four slaves, the limit is 125 crosspoints). In the same command string, up to 25 crosspoints per mainframe can be closed. If either limit is exceeded, an IDDCO results.
3. The maximum value of the column parameter depends on the configuration (12 for standalone, 60 for master with four slave units). An IDDCO results if the maximum value is exceeded.
4. This command is equivalent to multiple light pen operation(s).

Example

```
PRINT #1, "OUTPUT 18;NA55X"                ' Open one crosspoint
PRINT #1, "OUTPUT 18;NA55,A56,B49,B50X"    ' Open multiple crosspoints
```

5.9.15 O — Digital output

Purpose To set the states of the digital output lines.

Format Ovvvvv

Parameters vvvvv=00000 to 65535 Decimal value of digital output

Default Upon power-up or after receiving a DCL, SDC, or R0X command, the instrument defaults to O00000 (all digital outputs set to logic low).

Description This command is a decimal representation of the states of individual output lines of the digital I/O port, where "1" is logic high and "0" is logic low. Bit assignments and corresponding connector pins are shown below:

Bit Position	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit Weight	32768	16384	8192	4096	2048	1024	512	256	128	64	32	16	8	4	2	1
Digital	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

Programming notes

1. In a master/slave configuration, only the output of the master unit is updated.
2. Leading zeros are not necessary in the parameter value.
3. This command is equivalent to a multiple light pen operation(s).
4. Output is negative true logic. Setting bit high will make output go low (sink).

Example

```
PRINT #1, "OUTPUT 18;O15X"    ' Set bits <3-0> high
PRINT #1, "OUTPUT 18;O0X"     ' Restore default condition
```

5.9.16 P — Clear crosspoints

Purpose To clear all crosspoints at the specified setup.

Format Pn

Parameters

n=0	Present relay setup
n=1 to 100	Stored relay setup

Description The P command clears all crosspoints in the setup indicated by its parameter. If the present relay setup (zero) is specified, all crosspoint relays are opened immediately. If setup stored in memory (1-100) is specified, all crosspoints of that setup are cleared.

Programming note This command is equivalent to multiple front panel key presses.

Example

```
PRINT #1, "OUTPUT 18;P0X"          ' Open all relays
PRINT #1, "OUTPUT 18;P20X"         ' Clear relay setup 20
```

5.9.17 Q — Delete setup

Purpose To delete a setup from memory.

Format Qn

Parameters

n=1 to 100	Stored relay setup

Description During execution of this command, setups "n+1" through 100 are shifted down to the next lower location in memory ("n+1" to "n"... 100 to 99). Then, all crosspoints of setup #100 are cleared. The front panel display is blanked during a delete operation.

Programming note The command Q100 clears all crosspoints of relay setup 100.

Example

```
PRINT #1, "OUTPUT 18;Q50X"         ' Delete relay setup #50 from memory
```

5.9.18 R — Restore defaults

Purpose To restore the Model 708A to factory default conditions.

Format Rn

Parameters n=0 Restore factory defaults

Description An R0 command performs the following actions:

- All setups stored in memory are cleared.
- Make/Break and Break/Make rows are cleared.
- A Device Clear operation (all crosspoint relays are opened, Relay Step pointer is set to 000, Memory Step is set to 001).

DDC parameters are set to the values shown below:

A0	Initiate trigger on falling edge of External Trigger pulse.
B0	Set Matrix Ready output signal to negative true.
E000	Set edit pointer to present relay setup.
F0	Disable triggers.
G0	Set full output format, all data sent in one talk.
K0	Send EOI with last byte, hold-off on X until ready.
M000	Disable all SRQ sources.
O00000	Set all digital outputs to logic low.
S00000	Set user settling time to zero.
T7	Trigger Model 708A on external trigger pulse.
V00000000	De-select all rows for make/break.
W00000000	De-select all rows for break/make.
Y0	Set terminator characters of <CR> <LF>.

Programming note The primary IEEE-488 address and master/slave operation are not affected by the Restore command.

Example

```
PRINT #1, "OUTPUT 18;R0X"          ' Restore default conditions, clear setups
```

5.9.19 S — Programmed settling time

Purpose To program the settling time.

Format Sn

Parameters n=0 to 65000 Time in ms

Default Upon power-up or after receiving a DCL, SDC, or R0X command, the instrument defaults to S0 (programmed settling time of zero).

Description With the S command, you can program the settling time (up to 65 seconds). The programmed settling time starts after the longest relay settling time has elapsed.

Programming notes

The total settling time equals the longest relay settling time of any card in the system plus any user-programmed settling time. Figure 5-16 shows a timing diagram of the settling times. Additional timing diagrams are given in paragraph 4.8.2.

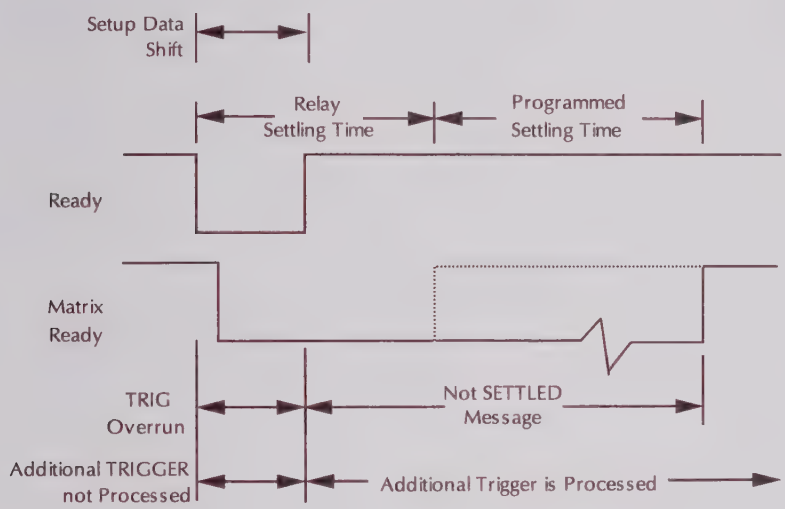


Figure 5-16
READY and MATRIX READY signal timing

Example

```
PRINT #1, "OUTPUT 18;S5000X"      ' Program 5 second (5000 ms) settling time
PRINT #1, "OUTPUT 18;S0X"         ' Restore default condition (0 ms)
```

5.9.20 T — Trigger

Purpose

To select the trigger source.

Format

Tn

Parameters

n=0 or 1	Trigger on talk
n=2 or 3	Trigger on GET
n=4 or 5	Trigger on X
n=6 or 7	Trigger on External Trigger pulse

Default

Upon power-up or after receiving a DCL, SDC, or R0X command, the instrument defaults to T7 (Trigger on External Trigger pulse).

Description

With the trigger command, you can determine the trigger source over the bus or from an external trigger pulse. A valid trigger increments the Relay Step pointer by one, stopping at 100, and copies the setup data indicated by the new value to the relays.

Programming notes

1. Duplication of trigger sources allows compatibility with other Keithley IEEE-488 instruction sets.
2. Disabling triggers before changing the trigger source is a good programming practice.

3. If the unit is re-triggered while it is still processing a previous trigger, a Trigger Overrun or Trigger Before Settling Time Expired error occurs, depending on when the additional trigger occurs. The timing diagrams are shown in paragraph 4.8.2.
4. To trigger the instrument when using the trigger on talk, you must send the talk command derived from the correct primary address. The factory default primary address is 18. Trigger on talk does not occur when the Model 708A becomes a talker, but rather as the controller requests the first byte of data from the unit.
5. Trigger on GET allows the fastest IEEE-488 triggering response.
6. The X character that is sent when programming a trigger on X source triggers the instrument.

Example

```
PRINT #1, "OUTPUT 18;F0T0X"        ' Disable triggers, program trigger on talk.
PRINT #1, "OUTPUT 18;F1X"          ' Enable triggers
PRINT #1, "ENTER 18"               ' Trigger next setup
LINE INPUT #2, A$
PRINT #1, "OUTPUT 18;F0T2X"        ' Disable triggers, program trigger on GET
PRINT #1, "OUTPUT 18;F1X"          ' Enable triggers
PRINT #1, "TRIGGER 18"             ' Trigger next setup
```

5.9.21 U — Status

Purpose

To obtain instrument status and system configuration.

Format

Un
Un,s
Un,u

Parameters

n = 0	Send machine status word.
n = 1	Send error status word.
n = 2,s	Output setup "s" (0-100) with present G format.
n = 3	Send value of RELAY STEP pointer.
n = 4	Send number of slaves.
n = 5,u	Send ID of each card in unit "u" (0-4).
n = 6	Send longest relay settling time.
n = 7	Send digital input of unit.

Description

Overview

By sending the appropriate U command and then addressing the instrument to talk as with normal data, you can obtain information on machine status, error conditions, and other data.

U0 Machine status word

The format of U0 is shown in Figure 5-17. The letters correspond to modes programmed by the respective device-dependent commands. Returned values correspond to the programmed numeric values. The values shown in Figure 5-17 are the default values.

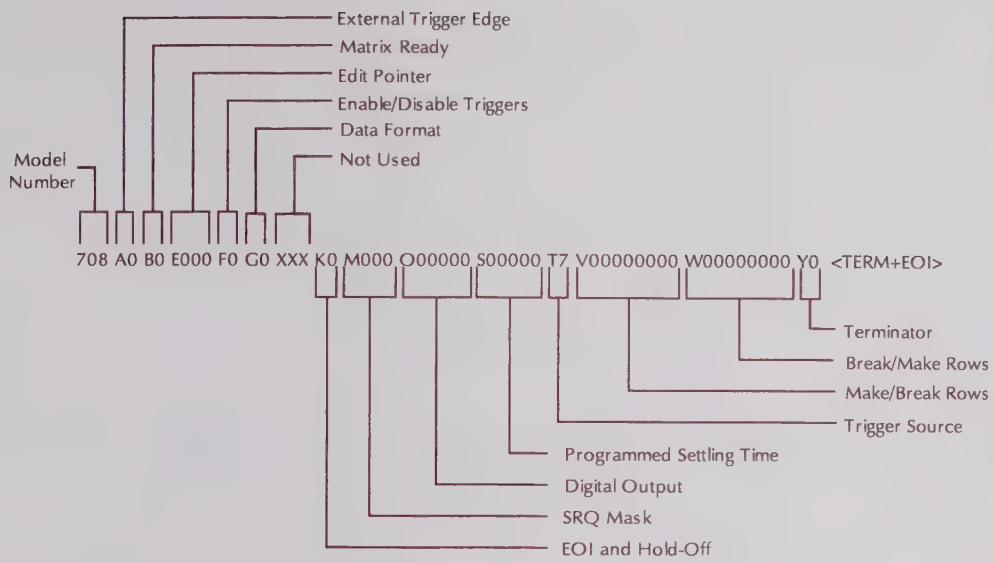


Figure 5-17
U0 machine status word

U1 Error status word

The U1 command allows access to Model 708A error conditions. The error status word (Figure 5-18) is a string of ASCII characters representing binary bit positions. Reading the U1 status clears the error bits. An error condition is flagged in the serial poll byte while any bits in the error status word are set. The instrument can be programmed to generate an SRQ when an error condition occurs (see paragraph 5.9.12).

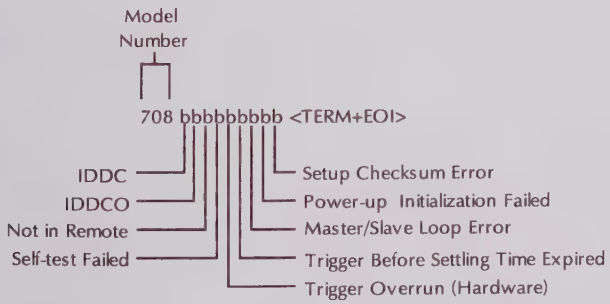


Figure 5-18
U1 error status word

The various bits in the U1 error status word are set when the following conditions are present:

IDDC — An invalid device-dependent command (IDDC) is received.

IDDCO — An invalid device-dependent command option (IDDCO) is received.

Not in Remote — An X command is received over the bus, but the Model 708A is not in remote.

Self-test Failed — The self-test detects a program ROM checksum error or a RAM error.

Trigger Overrun (Hardware) — A trigger is received before the Ready signal is asserted. The trigger is ignored.

Trigger Before Settling Time Expired — A trigger is received before the Matrix Ready signal is asserted. The trigger is processed.

Master/Slave Loop Error — There is a communication or timing error in the master/slave loop.

Power-up Initialization Failed — The power-up routine has detected a checksum error in the information from one or more cards.

Setup Checksum Error — The power-up routine detects a checksum error in one or more set-ups stored in memory. (The affected setups are cleared.)

U2,n Formatted setup

With the U2 command, you can request the Model 708A to output data of either the present relay setup (n = 0) or a stored setup (1 < = n < = 100) according to the G format presently in effect. (See paragraph 5.9.7.)

U3 Relay step pointer

The U3 command (Figure 5-19) requests the value of the Relay Step pointer, which indicates the last setup sent to the relays (000 < = nnn < = 100).

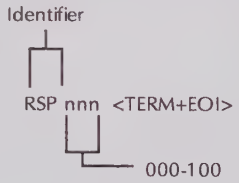


Figure 5-19
U3 relay step pointer

U4 Number of slaves

With the U4 command (Figure 5-20), you can request the number of slaves present in a master/slave loop configuration (between 1 and 4).

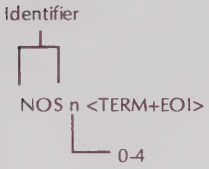


Figure 5-20
U4 number of slaves

U5,u Card IDs

By specifying a unit number in the U5 command (0 for master, 1-4 for slaves), you can request the model numbers of the cards present in each mainframe. The output format is shown in Figure 5-21. The character string for an empty slot is "NONE".

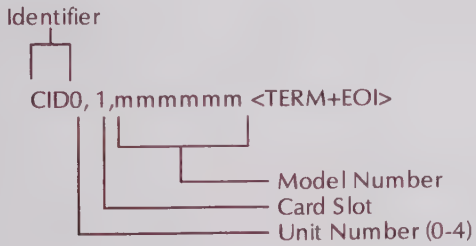


Figure 5-21
U5 card identification

U6 Relay settling time

The U6 command (Figure 5-22) requests the Model 708A to output the longest relay settling time of all cards in the system (expressed in milliseconds).

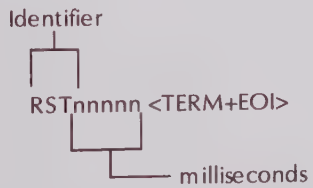


Figure 5-22
U6 relay settling time

U7 Digital input

The U7 command (Figure 5-23) requests a decimal value of the inputs at the digital I/O port. In master/slave configurations, the digital input of the master unit is sent.

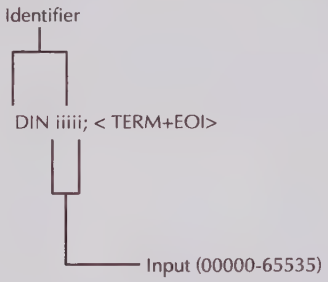


Figure 5-23
U7 digital input

Programming notes

1. The instrument transmits the appropriate status word only once each time the corresponding U command is received.
2. To ensure that correct status is indicated, the status word should be requested immediately after the command is transmitted. The status sent by the Model 708A is that which is present at the time it is instructed to talk, not at the time the U command is received.
3. The bits in the U1 error status word latch and remain in that condition until the U1 word is read.
4. The programmed terminator (default CR LF) is transmitted at the end of each status word. Also, EOI is transmitted at the end (unless disabled with the K command).
5. If no U command has been received, the PRINT #1, "ENTER 18" and LINE INPUT #2, A$ commands request the letter (x) and number (nn) of the software revision for a stand-alone unit or the master unit of a master/slave configuration (708Axnn). It is sent with two trailing spaces plus the terminator and EOI.

5.9.22 V — Make/Break

Purpose To select rows for make/break operation.

Format Vabcdefgh

Parameters

abcdefgh=	00000000	All rows de-selected for make/break
	to	
	11111111	All rows selected for make/break

Description The V command selects individual rows for make/break (make-before-break) operation. A "1" in the respective row field selects make/break; a "0" de-selects make/break operation.

Programming notes

1. Specifying fewer than eight numbers in the parameter field (e.g., V1111) is invalid. The Model 708A takes no action on the rows and flags an IDDCO error.
2. The rows can be programmed for one of three switching options: make/break, break/make, or don't care. A row cannot be selected for both make/break and break/make at the same time. Selecting it for one de-selects it for the other.
3. When switching current sources, use make/break operation to keep current flowing and eliminate switching transients. When switching voltage sources, use break/make operation to avoid momentary shorting of two paths together.
4. Given the present states and actions performed, the next states of the rows are listed below:

Present state	Action	Next state
Don't Care	Select Make/Break	Make/Break
	De-select Make/Break	Don't Care
Make/Break	Select Make/Break	Make/Break
	De-select Make/Break	Don't Care
Break/Make	Select Make/Break	Make/Break
	De-select Make/Break	Break/Make

Example

```
PRINT #1, "OUTPUT 18;V11110000X"     ' Select rows ABCD for make/break
PRINT #1, "OUTPUT 18;V00000000X"     ' Restore default condition
```

5.9.23 W — Break/Make

Purpose

To select rows for make/break operation.

Format

Wabcdefgh

Parameters

abcdefgh=	00000000	All rows de-selected for break/make
	to	
	11111111	All rows selected for break/make

Description

The W command selects individual rows for break/make (break-before-make) operation. A "1" in the respective row field selects break/make; a "0" de-selects break/make operation.

Programming notes

1. Specifying fewer than eight numbers in the parameter field (e.g., W1111) is invalid. The Model 708A takes no action on the rows and flags an IDDCO error.
2. The rows can be programmed for one of three switching options: make/break, break/make, or don't care. A row cannot be selected for both make/break and break/make at the same time. Selecting it for one de-selects it for the other.
3. When switching current sources, use make/break operation to keep current flowing and eliminate switching transients. When switching voltage sources, use break/make operation to avoid momentary shorting of two paths together.
4. Given the present states and actions performed, the next states of the rows are listed below:

Present State	Action	Next State
Don't Care	Select Break/Make	Break/Make
	De-select Break/Make	Don't Care
Make/Break	Select Break/Make	Break/Make
	De-select Break/Make	Make/Break
Break/Make	Select Break/Make	Break/Make
	De-select Break/Make	Don't Care

Example

```
PRINT #1, "OUTPUT 18;W11110000X"     ' Select rows ABCD for break/make
PRINT #1, "OUTPUT 18;W00000000X"     ' Restore default condition
```

5.9.24 X — Execute

Purpose

To direct the Model 708A to execute device-dependent commands received since the last X.

Format

<command> X

Description

The execute command is implemented by sending an ASCII X over the bus. Its purpose is to direct the Model 708A to execute other device-dependent commands. Generally, the execute character is the last byte sent in the command string; however, there may be some cases when it is desirable to send a string of characters at one time and then send the execute character later on.

Programming notes

1. Commands or command strings sent without the X character are not executed at that time, but they are stored in an internal command buffer for later execution once the X character is finally received.
2. The X character can also be used to trigger, as described in paragraph 5.9.19.
3. Commands are not necessarily executed in the order sent (see Table 5-10). To force a particular command sequence, include the X character after each command in the command string.

Example

```
PRINT #1, "OUTPUT 18;E1X"            ' Execute single command
PRINT #1, "OUTPUT 18;E1CA47X"        ' Execute multiple commands
PRINT #1, "OUTPUT 18;T6XA1XR1X"      ' Force command sequence
PRINT #1, "OUTPUT 18;G2Y1"           ' Send string without execute
PRINT #1, "OUTPUT 18;X"              ' Now execute command string at later time
```

5.9.25 Y — Terminator

Purpose

To select the ASCII terminator sequence that marks the end of the instrument's data string or status word.

Format

Yn

Parameters

n = 0 <CR><LF>
n = 1 <LF><CR>
n = 2 <CR>
n = 3 <LF>

Default

Upon power-up or after receiving a DCL, SDC, or R0X command, the instrument defaults to Y0 (<CR><LF>).

Description

By using the Y command, you can program the number and type of terminator characters the instrument sends at the end of its data string. Available terminator characters are the commonly used CR (carriage return, ASCII 13) and LF (line feed, ASCII 10) characters. These terminator characters are recognized by most controllers.

Programming notes

1. EOI is another method that can be used to terminate the controller input sequence, as discussed in paragraph 5.9.10. EOI is asserted with the last terminator byte when enabled.
2. The programmed terminator is sent at the end of the transmission each time the Model 708A is addressed to talk, regardless of the selected data format.
3. Status word programming is covered in paragraph 5.9.20.

Example

```
PRINT #1, "OUTPUT 18;Y2X"          ' Terminator on CR
PRINT #1, "OUTPUT 18;Y0X"          ' Restore default
```

5.9.26 Z — Copy setup

Purpose

To copy a setup from relays or memory to relays or memory.

Format

Zm,n

Parameters

m = 0-100 Copy present relay setup from...
n = 0-100 Copy present relay setup to...

0,n = Copy present relay setup to stored setup "n" (1-100)
n,0 = Copy stored setup "n" (1-100) to present relay setup
m,n = Copy setup "m" (0-100) to setup "n" (0-100)

Description

By specifying a source and destination in the Z command, you can copy data between stored setups and between the relays and setups stored in memory. Copying a setup to the relays sets the Relay Step pointer to that setup.

Programming note

The Z0,0X command sends the present relay setup to the relays. There is no effect on the relays, but the Relay Step pointer will be reset to 000.

Example

```
PRINT #1, "OUTPUT 18;Z0,10X"       ' Copy present relay setup to setup 10
PRINT #1, "OUTPUT 18;Z20,0X"       ' Copy setup 20 from memory to relays
PRINT #1, "OUTPUT 18;Z10,20X"      ' Copy setup 10 to setup 20
```

5.10 Relay command combinations

There are four device-dependent commands that have an immediate effect on relay states:

- E0N... — Point to relays, open specified crosspoints.
- E0C... — Point to relays, close specified crosspoints.
- P0 — Open all relays.
- Zn,0 — Copy setup "n" to relays.

Combinations of these commands in the same command string cause only one relay switching operation when the X character is received. The command hierarchy (E, P, Z, N, C) determines the final data that is sent to the relays. This is shown in the following examples.

Example 1

The command string "E0P0CA1X" sets the edit pointer to the present relay setup, opens all relays, and closes crosspoint A1. A1 will be the only closed crosspoint.

Example 2

The string "E0Z5,0CA1X" sets the edit pointer to the relays, copies stored setup #5 to the relays, and closes crosspoint A1. A1 will be closed regardless of the state of A1 in setup #5. The status of the relays will be a combination of setup #5 and a closed A1 crosspoint.

Example 3

The command string "E0Z5,0NA1X" points to the relays, copies setup #5 to the relays, and opens crosspoint A1. If setup #5 had specified A1 to be closed, the command NA1 overrides that. (A1 will not close, then open, as there will be only one relay switching operation.) The relays will reflect setup #5 and an open A1 crosspoint.

5.11 Timing considerations

Timing considerations for IEEE-488 programming include:

- Data transfer rates between the controller and Model 708A (stand-alone or master) over the IEEE-488 bus.
- Command string parse time within the stand-alone or master unit.
- Data transfer rates among the units in a master/slave loop.
- Execution times of the tasks defined by device-dependent commands.

The times needed for these actions are determined by the length of the command string, the number of units in a master/slave configuration, the types of commands, and the speed of the controller.

Typically, a command string sent to the Model 708A will transmit at a rate of four characters per millisecond. (Assuming the transfer speed of the controller does not affect the listening rate of the Model 708A.) For example, the CA1,CA5X command string will take 2ms to transmit from the controller to the Model 708A.

When the Model 708A is sending data to the controller (e.g., uploading setup data), the transmission rate will typically be 2.5 characters per millisecond.

The bus hold-off time for each command is the time from receipt of the "X" to "instrument configured." It includes the parsing time, data transfers within a master/slave loop, and command execution time.

Table 5-14 summarizes the total times (transmission plus hold-off) for device-dependent commands acting on a stand-alone unit. Table 5-15 summarizes these times for a master and one slave system. Bus hold-off times for individual command strings can be calculated by subtracting the transmission time (four characters per millisecond).

Table 5-14
Typical transmission and hold-off times — stand-alone

Description	Command	Time	Notes
External Trigger	A0X	4.8ms	
Matrix Ready	B0X	4.8ms	
Close Crosspoint(s)	CA1X	18.6ms	To relays
	CA1X	19.9ms	To setup 55
Edit Pointer	E0X	4.4ms	
	E100X	5.8ms	
Enable/Disable Triggers	F0X	4.8ms	
Data Format	G7X	4.4ms	
Insert Blank Setup	I1X	835ms	
	I100X	1.1ms	
Self-test	J0X	3.3ms	
EOI and Hold-off	K0X	4.4ms	
Download Setup	Lbbb...X	56.0ms	Binary format (G6,G7)
SRQ	M32X	4.9ms	
Open Crosspoint(s)			Similar to Close Crosspoints ("C") times
Digital Output	O65535X	5.8ms	
Clear Crosspoints	P0X	18.9ms	
	P55X	20.5ms	
Delete Setup	Q1X	828ms	
	Q100X	21.0ms	
Restore Defaults	R0X	628ms	
Programmed Settling Time	S0X	5.0ms	
	S65000X	7.3ms	
Trigger Source	T7X	4.8ms	
Status	U0X	4.5ms	
	U2,100X	6.8ms	
Make/Break Rows	V00000000X	124ms	With no B/M rows set
	V11111111X	134ms	With no B/M rows set
	V00001111X	153ms	With A,B,C,D as B/M
Break/Make Rows			Similar to Make/Break Rows ("V") times
Execute	X	3.2ms	
Terminator	Y0X	4.7ms	
Copy Setup	Z0,0X	21.1ms	
	Z0,100X	23.3ms	
	Z100,99X	21.6ms	

Table 5-15
Typical transmission and hold-off times — master and one slave

Description	Command	Time	Notes
External Trigger	A0X	12.3ms	
Matrix Ready	B0X	12.3ms	
Close Crosspoint(s)	CA1X	31.5ms	
Edit Pointer	E0X	17.4ms	
	E55X	18.8ms	
Enable/Disable Triggers	F0X	18.5ms	
Data Format	G0X	11.7ms	
Insert Blank Setup	I1X	1.7s	
	I100X	49.9ms	
Self-test	J0X	3.4ms	
EOI and Hold-off	K0X	11.6ms	
Download Setup	Lbbb...X	68.5ms	Binary format (G6,G7)
SRQ	M32X	12.0ms	
Open Crosspoint(s)			Similar to Close Crosspoints ("C) times
Digital Output	O65535X	12.9ms	
Clear Crosspoints	P0X	47.8ms	
	P55X	48.8ms	
Delete Setup	Q1X	1.7s	
	Q100X	49.8ms	
Restore Defaults	R0X	1.4s	
Programmed Settling Time	S0X	11.9ms	
	S65000X	14.6ms	
Trigger Source	T7X	12.3ms	
Status	U0X	11.8ms	
	U2,100X	14.2ms	
Make/Break Rows	V00000000X	265ms	With no B/M rows set
	V11111111X	284ms	With no B/M rows set
	V00001111X	324ms	With A,B,C,D as B/M
Break/Make Rows		10.5ms	Similar to Make/Break Rows ("V") times
Execute	X	11.5ms	
Terminator	Y0X	51.1ms	
Copy Setup	Z0,0X	47.2ms	
	Z0,100X	55.4ms	
	Z100,99X	49.9ms	

6

Principles of Operation

6.1 Introduction

This section contains a functional description of the Model 708A in block diagram form as well as details of the various sections of the instrument. Information is arranged to provide a description of each of the functional blocks within the instrument. Many of these descriptions include simplified schematics and block diagrams. Component layout drawings are located at the end of Section 8.

6.2 Overview

The Model 708A mainframe contains three circuit boards and one power supply. Relay cards that plug into the mainframe have analog circuits for signal paths and digital circuits for control. The block diagram in Figure 6-1 shows the interconnection of the mother board, front panel control board, display board, and backplane.

The following paragraphs describe Model 708A circuitry by function. Some functions are controlled by more than one board (e.g., relay control circuits and display circuits).

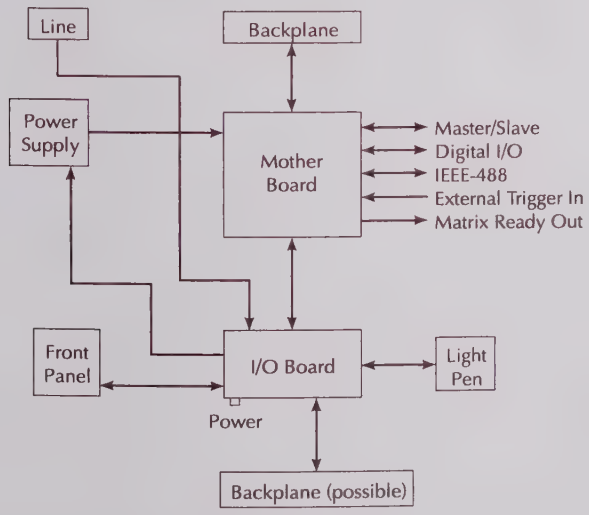


Figure 6-1
Model 708A block diagram

6.3 Microcomputer

The Model 708A is controlled by an internal microcomputer. As shown in Figure 6-2, the digital board contains the CPU, memory, and the following associated components:

- 68B09 microprocessor (U104)
- Oscillator (Y101)
- Power-up reset (U111)
- Address decoding PALs (U116, U117)
- 32K x 8-bit EPROM (U105)
- 32K x 8-bit RAM (U106) with battery back-up (BT101, U114)

The microcomputer centers around the 8-bit 68B09 microprocessor. The MPU has direct control over relay switching, front panel displays and switches, and rear panel interfaces (master/slave, digital I/O, IEEE-488 bus, and triggers).

Although the 68B09 microprocessor will operate at frequencies up to 8MHz, a clock frequency of 7.15909MHz is used to reduce interference with instruments that use measurement signals with harmonics of 1MHz. Crystal Y101 provides timing for the microprocessor. Internally, the clock frequency is divided down by four to obtain an operating frequency on the microprocessor bus of 1.78977MHz.

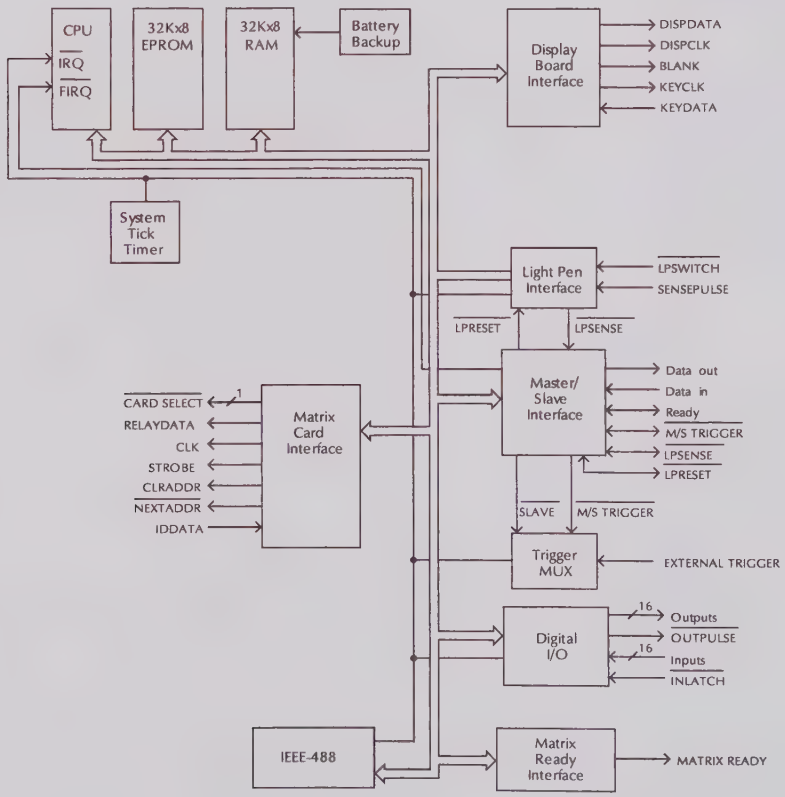


Figure 6-2
Digital board block diagram

6.3.1 Reset circuit

The reset circuit, which is based on an 8211 (or 6728) voltage detector (U111), senses the output of the power supply. When the output drops below approximately 4.6V, the 8211 asserts the RESET (low true) line. Two 1% resistors (R115 and R116) form a voltage divider, which is calibrated to match the comparator threshold voltage of the 8211 by either removing or leaving in R117, which is in parallel with R116.

During power-off or brownout conditions, the RESET line must be asserted before the power supply drops into the comparator threshold range (4.25 to 4.5 volts) of the DS-1210 non-volatile RAM controller (U114). During power-up, capacitor C115 is charged up to delay the RESET line going high for 110 to 260ms.

6.3.2 Address decoding

U117, a 16P8A programmable array logic (PAL) chip, decodes microprocessor address lines A15-A12 for the 32K EPROM ($8000-$FFFF) and the 32K bytes of bank-selected RAM ($0000-$2FFF). Bank selection is used so that the RAM appears as 12K bytes of address space to the microprocessor.

U117 also decodes the three bank-select lines (BS3-BS0) from the PB6-PB4 outputs of U103, a 6522A versatile interface adapter (VIA). The RAM is decoded as 8K bytes ($0000-$1FFF) and six 4K byte banks, which appear to the microprocessor at addresses $2000-$2FFE. This lets the microprocessor select one of the six 4K byte banks.

Address decoding for peripheral devices on the microprocessor bus is performed by another 16P8A PAL (U116). Peripheral devices are decoded at 16-byte intervals in the address range of $3800-$38FF. These include, for example, a 6522A VIA, a 65C21 peripheral interface adapter (PIA), and a 68B50 asynchronous communication interface adapter (ACIA).

6.3.3 Memory

The 32K bytes of instrument operation software are stored in U105 ($8000-$FFFF), which is a 27256 EPROM.

U106 ($0000-$2FFF) is a 32K byte static CMOS RAM chip used for storing relay setups and as a scratchpad during normal operation. Its power source and chip enable lines are routed through U114, a DS-1210 NVRAM controller. Figure 6-3 shows a simplified schematic of the RAM and battery backup circuitry.

The NVRAM controller performs the functions of switching the RAM power source between Vcc and the lithium battery (BT101). It also disables chip enable (CE) to the RAM when Vcc is outside the specified limits (paragraph 6.3.1).

In addition, if the battery power goes below a specified limit while Vcc is not present, a DS-1210 chip normally inhibits the second chip enable signal to the RAM after Vcc is restored. Since this feature is not used in the Model 708A, the software always does a dummy read of memory locations $0000-$0001 on power-up to get past the second chip enable cycle. This permits the Model 708A to operate properly with no battery, or if the battery has been replaced.

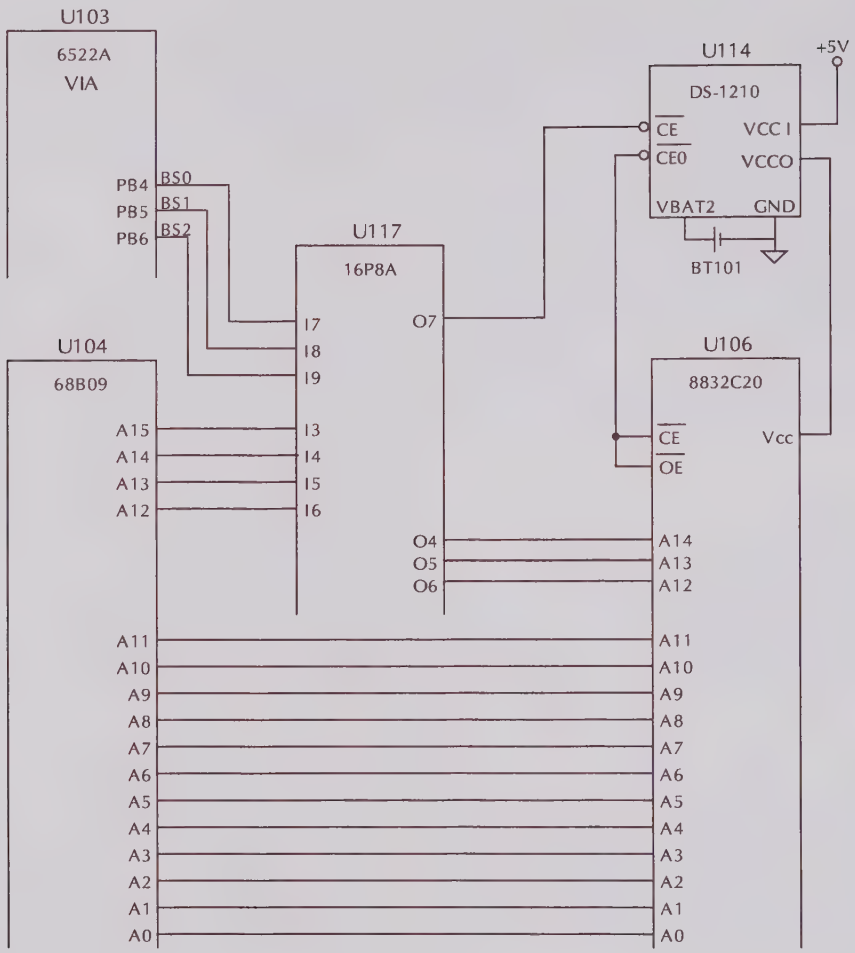


Figure 6-3
RAM and battery backup

6.4 Relay control circuitry

The relay control circuits reside on the backplane board, mother board, and each switching card.

The backplane board acts as a passive conduit for:

- Control signals from the mother board to the switching cards and response from the cards to the mother board.
- Power lines to the switching cards.
- Expansion of analog signals among the switching cards.

Operations of relay control circuitry on the mother board and a typical switching card are described in the following paragraphs.

6.4.1 Switching card interface

A simplified schematic and timing diagram of the mother board's card interface are shown in Figure 6-4 and Figure 6-5.

The microprocessor reads card identification data from the EPROM on each installed card during power-up and sends relay control data to the cards during the course of operation. This data is sent and received in serial form.

On the mother board, U131, U129, U128, U127, and U130 form an 8-bit parallel-in, serial out data converter. When the microprocessor executes a write to the address decoded for U131 (a 74HCT165 shift register), the data bus contents are loaded into U131, and all ones are loaded into U129 (74HCT165) causing its output OH to go high.

At the end of the write cycle, the SELECT RELAYDATA decode line goes high, causing the output of the U128 (74HCT08) AND gate to go high. This signal (ACTIVE) gates the microprocessor E clock through a U127 (74HCT00) NAND, which is buffered by U137 and sent to the cards as the CLK signal. Clock cycles are counted by the U129 shift register. After 8 cycles, OH of U129 returns low, disabling further CLK pulses.

The U130 (74HCT74) flip-flop and another U127 NAND gate are used to create an inverted version of CLK, which does not start until after one cycle of CLK. This signal is used to shift data out of the U131 RELAYDATA shift register.

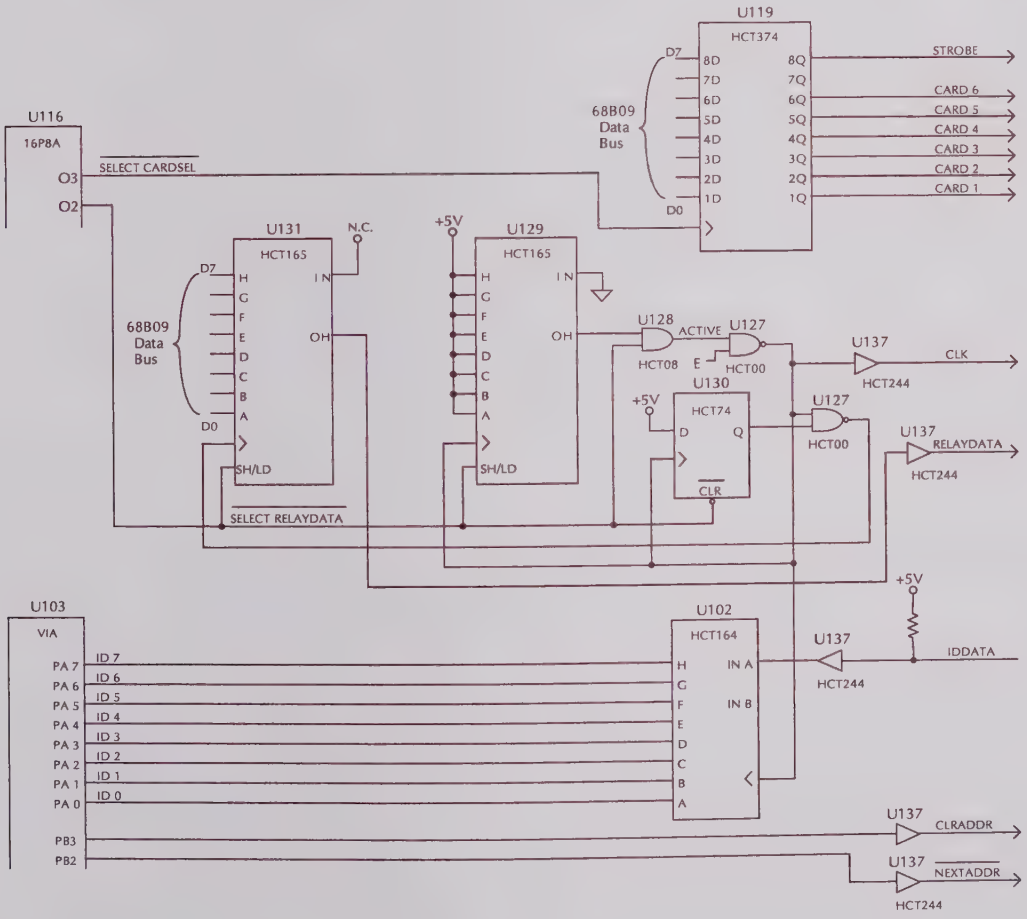


Figure 6-4
Matrix card interface simplified schematic

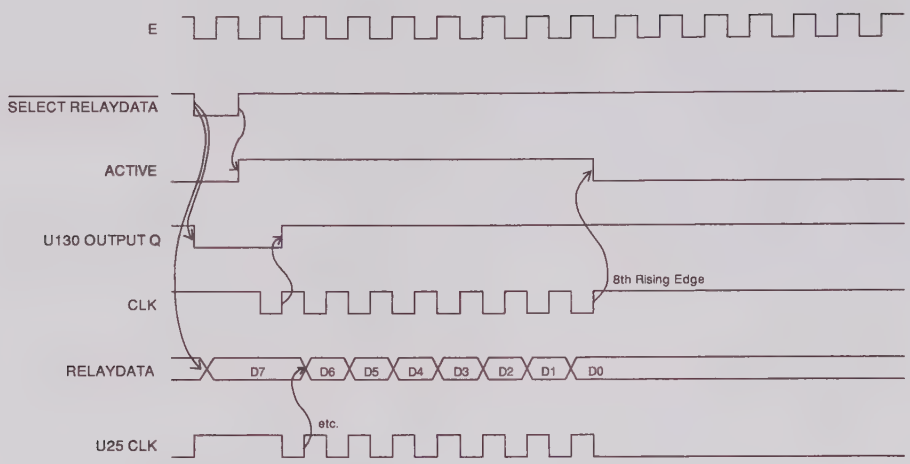


Figure 6-5
Matrix card interface timing diagram

6.4.2 Switching card logic

See Figure 6-6 for a block diagram of the logic on a typical switching card.

On the cards, the CLK and RELAYDATA signals are buffered and sent to a string of UCN-5841 serial input latched driver chips. The CLK signal is sent in parallel to all of the driver ICs. The serial data out of one driver is connected to the serial data in of the next driver.

ID data circuits

Each card has a 2764 EPROM that contains the following identification data:

- Card model number
- Relay (hardware) settling time
- Relay configuration table

The configuration table defines the location of each relay driver within the serial RELAYDATA bit stream. The table is necessary because the physical layout of cards varies. In addition, the table accommodates row and/or column isolation relays, such as those on the Model 7072 card.

To read this ID data, the following sequence is performed at power-up. Figure 6-7 shows the general timing of this sequence.

1. The CARDSEL line is brought low, enabling the EPROM outputs. This line remains low throughout the ID data transmission sequence.
2. The CLRADDR line (generated by port signal PB3 of the digital boards VIA) is pulsed high to clear the 12-bit address counter (74HCT4040) to zero. At this point, an EPROM address of zero is selected. This pulse occurs only once.
3. The NEXTADDR line (PB2 of VIA) is set low. This increments the counter and enables parallel loading of the parallel-to-serial converter (74HCT165). NEXTADDR is kept low long enough for the counter to increment and the EPROM outputs to stabilize. This sequence functions because the LOAD input of the parallel-to-serial converter is level-sensitive rather than edge-sensitive. The first EPROM address used by the Model 708A is location one, not zero.
4. The same CLK signal that shifts RELAYDATA into the relay driver also clocks the parallel-to-serial converter to shift all eight data bits from the converter to the digital board via the IDDATA line. This means that a byte of RELAYDATA must be sent to a card to get the next byte of IDDATA.

Steps 3 and 4 are repeated until all the necessary EPROM locations are read.

As shown in Figure 6-7 of the mother board, IDDATA is converted back to parallel by U102 (74HCT164) and is read by the microprocessor through the port A lines of U103 (6522A VIA)(VIA $3860-$386F).

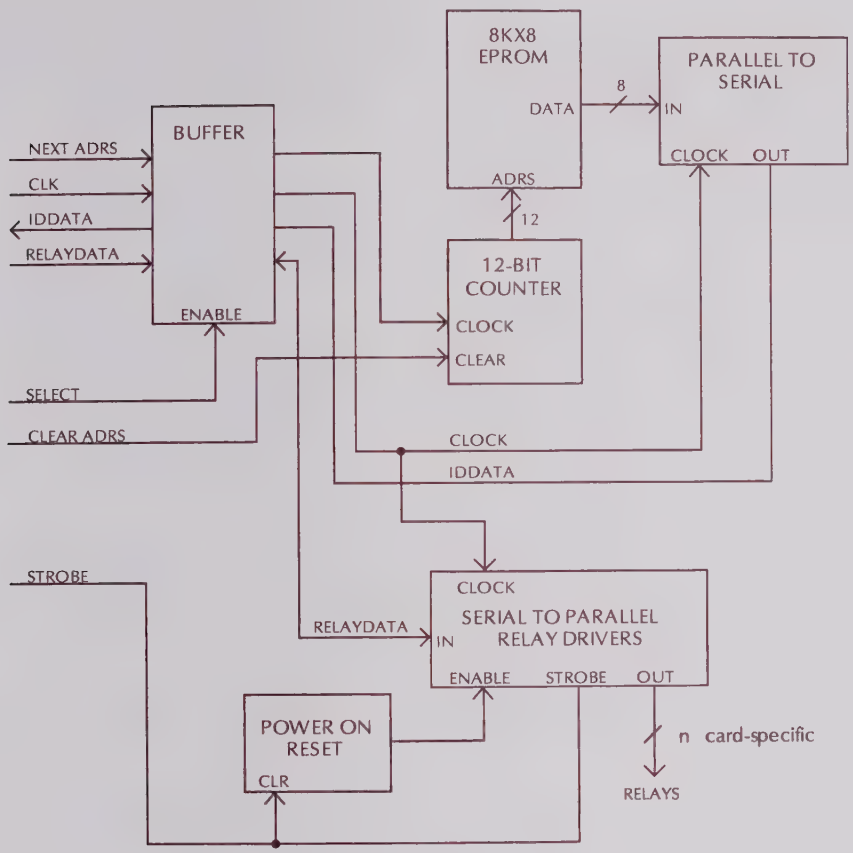


Figure 6-6
Typical matrix card logic block diagram

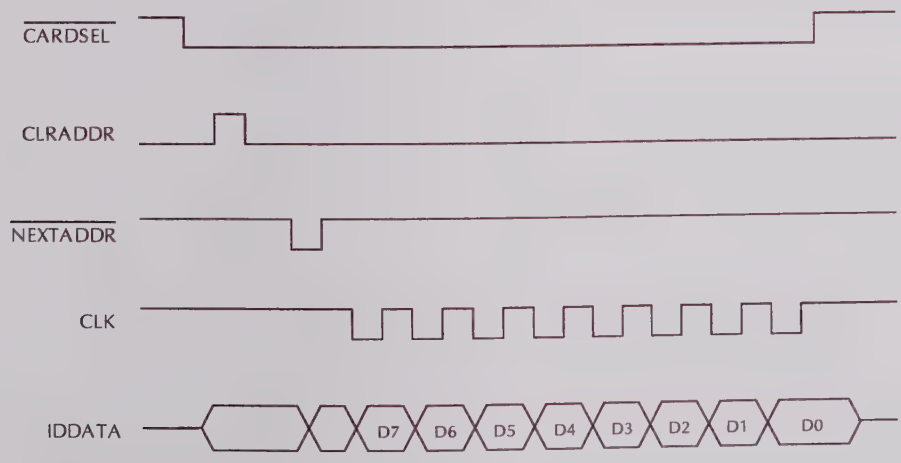


Figure 6-7
IDDATA timing diagram

Relay control

The CLK, RELAYDATA, and IDDATA lines are bused to the card slot on the backplane board. A separate card select signal is sent to the card to enable it for receiving RELAYDATA and sending IDDATA. The microprocessor controls the card select signals through U119 (74HCT374) on the mother board, which is decoded as an output port on the microprocessor bus.

The relays are controlled by the serial data transmitted via the RELAYDATA lines. Bytes for each card are shifted serially into latches located in the relay drivers. The serial data is fed in through the DATA lines under control of the CLK signal. As data overflows one register, it is fed out the Q'S line of that register to the next IC down the chain.

Once all the bytes have been shifted into the card in the switching system, the STROBE line is set high to latch the relay information into the Q outputs of the relay drivers, and the appropriate relays are energized (assuming the driver outputs are enabled). Logic convention is such that the corresponding relay driver output must be low to energize the associated relay, while the output is high when the relay is de-energized. The STROBE signal is received by all cards regardless of the state of their respective card select lines.

Power-on safeguard

Each card has a power-on safeguard circuit to ensure that relays do not randomly energize upon power-up. Two NAND gates of a 74HCT00 are configured as an R-S flip-flop. On power-up, the Q output of the flip-flop is set high, holding the low true OEN (output enable) pins of the relay drivers high. Hence, the driver outputs are disabled, and all relays remain de-energized regardless of the relay data information present at that time.

The falling edge of the first STROBE pulse that comes along (to load relay data) clears the R-S flip-flop, setting the OEN pins low and enabling the driver outputs. At this time, valid relay control data has been sent to the cards and is present in the latches of the driver chips. This action allows the relays to be controlled by the transmitted relay data information.

NOTE

The STROBE signal can be high or low on power-up since the outputs of U119 (74HCT374) on the mother board are undefined at power-on. Since the falling edge on STROBE, after the output enable circuit times out, enables the relay driver outputs, the power-up software must set STROBE low before the timeout. It then pulses STROBE high after the relay driver shift registers have been cleared.

A hold-off period (typically 470ms) is included in the safeguard circuit to guard against premature enabling of the relays. The time constant of the hold-off period is determined by an R-C network.

6.5 Display circuitry

Model 708A display circuitry includes components needed to control the front panel annunciator LEDs, crosspoint LEDs, and to read front panel switches.

The display circuitry is on the front panel control board and mother board. See Figure 6-8 for a block diagram of the display board and Figure 6-9 for a simplified schematic of the display board interface on the mother board. The front panel display is multiplexed as 12 columns for the card columns and one column containing the discrete annunciator LEDs TALK, LSTN, REM, COPY, and ERR. Display segment assignments for the multiplexed columns are shown in Table 6-1.

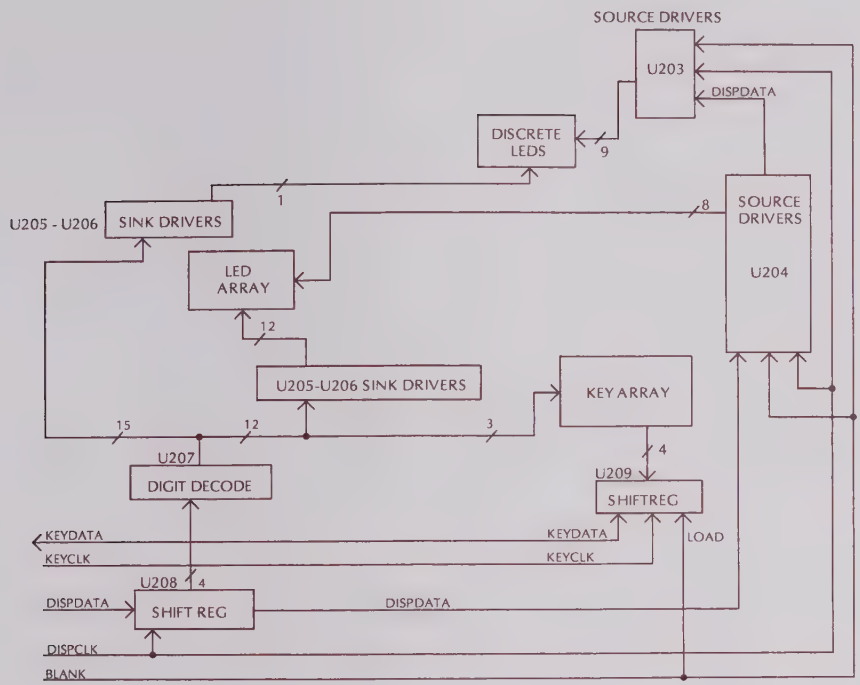


Figure 6-8
Display board block diagram

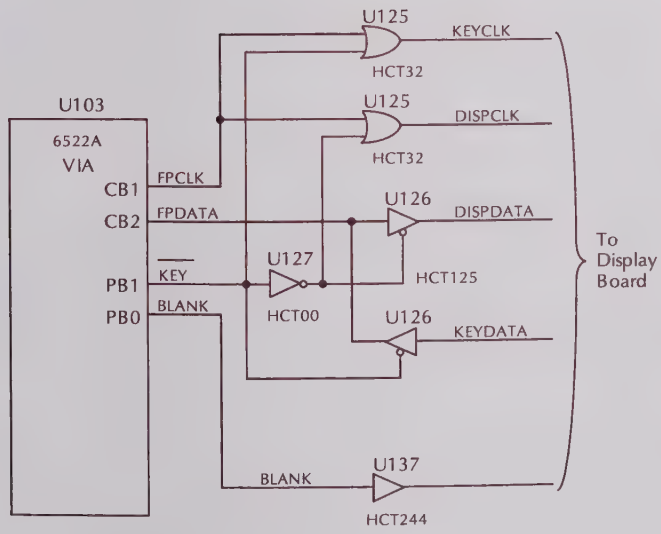


Figure 6-9
Display interface simplified schematic

Table 6-1
Display segment assignments

		COLUMN												
		1	2	3	4	5	6	7	8	9	10	11	12	13
ROW	A	DS400	DS401	DS402	DS403	DS404	DS405	DS406	DS407	DS408	DS409	DS410	DS411	—
	B	DS412	DS413	DS414	DS415	DS416	DS417	DS418	DS419	DS420	DS421	DS422	DS423	—
	C	DS424	DS425	DS426	DS427	DS428	DS429	DS430	DS431	DS432	DS433	DS434	DS435	—
	D	DS436	DS437	DS438	DS439	DS440	DS441	DS442	DS443	DS444	DS445	DS446	DS447	—
	E	DS448	DS449	DS450	DS451	DS452	DS453	DS454	DS455	DS456	DS457	DS458	DS459	—
	F	DS460	DS461	DS462	DS463	DS464	DS465	DS466	DS467	DS468	DS469	DS470	DS471	—
	G	DS472	DS473	DS474	DS475	DS476	DS477	DS478	DS479	DS480	DS481	DS482	DS483	—
	H	DS484	DS485	DS486	DS487	DS488	DS489	DS490	DS491	DS492	DS493	DS494	DS495	—
	TALK													DS496
	LSTN													DS497
	REM													DS498
	ERR													DS499
	COPY													DS500

6.5.1 Display data

The mother board sends display data (DISPDATA) to the front panel control board serially. Two bytes are required to select the column and row.

The cathodes are driven by U205 and U206. The anodes are driven by source drivers U203-U204 (UCN5895A) connected in a serial data chain. While new data is being sent to the display drivers, the BLANKOUT line is set high to disable the outputs. Display data is first shifted into the serial-to- parallel converter U208 (74HCT164) and then to the source drivers.

Four parallel outputs of U208 are decoded by the 4-to-16 decoder U207 (74HCT154). The outputs of this decoder drive the display cathodes through sink drivers U205-U206 (2597A).

6.5.2 Front panel keys

The front panel keys are SPST normally-open pushbutton switches. Each key is connected to one of the column drive outputs of decoder U207 (74HCT154) through a diode. The diodes isolate the columns from each other in case more than one key is pressed. As the display is multiplexed, each key column is pulled low in its turn, and the other columns float.

Each key is connected to Vcc through a pull-up resistor and to one of the inputs of parallel-to-serial converter U209 (74HCT165). The load input of U209 is connected to the BLANKOUT signal, so each time new data is sent to the display, another key gets latched into U209.

6.5.3 Display interface

The display interface circuitry of the mother board generates clock signals and communicates serial data for the front panel display and keyboard. The shift register of U103 (6522A VIA) controls the display and reads the key array. Pin CB1 is the clock signal (FPCLK), and pin CB2 is the data signal (FPDATA).

Signal FPCLK is generated for both serial output (display) and serial input (keyboard) operations. This single bi-directional port is converted to two uni-directional ports by two OR gates of U125 (74HCT32), two tri-state drivers of U126 (74HCT125), and a NAND gate of U127 (74HCT00) used as an inverter.

When the low true KEY signal (generated on VIA pin PB1) is asserted, DISPCLK is held high, KEYCLK follows FPCLK, the KEYDATA driver (U126) is enabled, and the DISPDATA driver (U126) is disabled.

When the low true KEY signal is negated, the KEYCLK signal is held high, and the DISPCLK signal follows FPCLK. The KEYDATA driver is also disabled, and the DISPDATA driver is enabled. The remaining signal that goes to the display board, BLANK, is generated by VIA output pin PB0.

6.5.4 Refresh display/read keyboard

The refresh display/read keyboard sequence is as follows:

NOTE

During power-on hardware initialization, the U103 shift register (6522A VIA) is configured for output, and the low true KEY signal is negated.

1. Set the BLANK line high.
2. Send two bytes of DISPDATA out the VIA shift register to drive the next column in the multiplex sequence.
3. Set the BLANK line low.
4. Configure the VIA shift register for input.
5. Assert the low true KEY line.
6. Read the VIA shift register to cause the KEYDATA to be shifted into the VIA.
7. Read the VIA shift register again to get the byte of KEYDATA.
8. Negate the low true KEY line.
9. Configure the VIA shift register for output.

6.6 Light pen interface

The light pen interface circuitry is on the front panel control board. A simplified schematic is shown in Figure 6-10.

The light pen is a self-contained unit requiring a 5 volt supply. It returns the following two TTL-compatible signals:

- SENSEPULSE — A low-going pulse of about 15µs width that occurs as the light intensity at the end of the pen rises above a preset threshold.
- LPSWITCH — A debounced switch signal that is low while the light pen pushbutton is depressed.

The rising edge of SENSEPULSE clocks a high into flip-flop U130 (74HCT74). This converts the signal into a level that can be read by the microprocessor through the PB7 input of U103 (6522A VIA) as signal LPSENSE (low true).

If the low true SLAVE signal from U108 (63821 PIA)($3850-385F) is high (i.e., the unit is either a stand-alone or master), the microprocessor reads its own U130 flip-flop. The output of U130 also gets driven onto the LPSENSE line of the master/slave connectors. If SLAVE is asserted, the microprocessor reads the LPSENSE signal from the master/slave connectors.

The microprocessor can clear flip-flop U130 by setting the LPRESET output of U103 high. This signal also gets driven onto the master/slave connectors by open-collector driver U134. This method permits the master and all slaves in a master/slave system to read and clear the U130 flip-flop in the master unit. Thus, one light pen can serve for all units, while each unit controls its own display for the scan routine.

The switch signal (low true LPSWITCH) goes to the CA1 interrupt input of the VIA, which is programmed to generate an IRQ interrupt on the falling edge of LPSWITCH. The interrupt service routine stops the normal display refresh multiplexing and takes over control of the display.

The routine then scans the display one column at a time, clearing flip-flop U130 before scanning each column. After the display is scanned, the processor examines the LPSENSE signal to determine if the light pen "sees" one of the LEDs that is presently being scanned.

If a master scans its display and receives no response from the light pen, it instructs the slaves to scan their displays. Each slave monitors the U130 flip-flop of the master to check whether or not the light pen "sees" any of the LEDs that are lit on its own display.

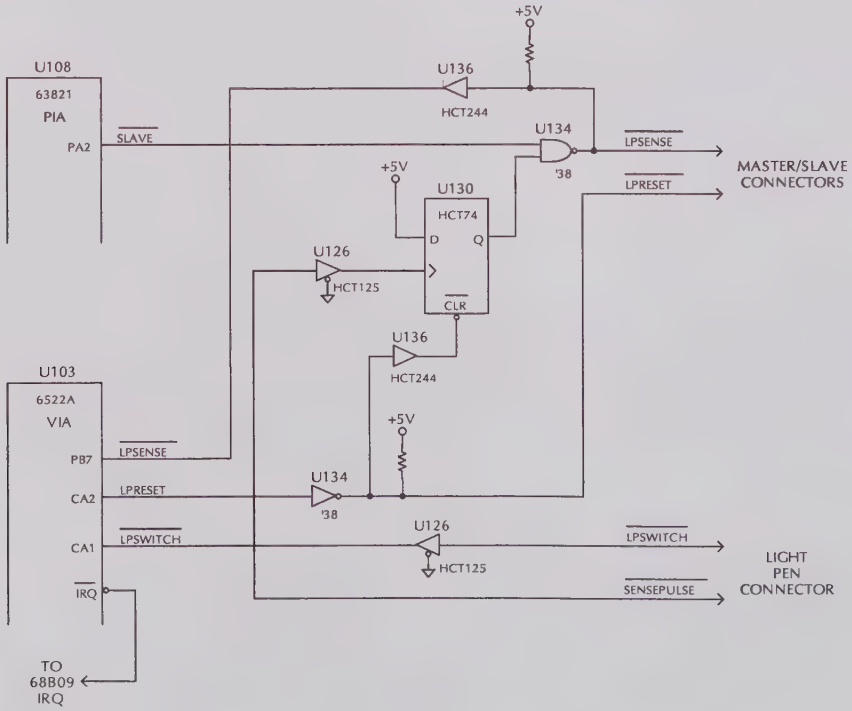


Figure 6-10
Light pen interface simplified schematic

6.7 Master/slave circuitry

The master/slave interface is a closed loop of serial communication and bused control signals. Its control circuitry resides on the mother board. See Figure 6-11 for a simplified schematic.

Each switching system has a Master/Slave In connector and a Master/Slave Out connector. Serial data is sent from the TXDATA pin of the output connector to the RXDATA pin of the input connector on the next switching matrix in the loop. All other interface signals (M/S TRIGGER, ALLREADY LPRESET, and LPSENSE) are common to input and output connectors. The light pen signals LPRESET and LPSENSE are described in paragraph 6.6.

6.7.1 Serial communication

Serial data communication is managed by U107 (68B50 ACIA) and automatic retransmit logic: a U127 NAND gate used as an inverter, U128 AND gates, and U125 OR gate.

The RTS (low true) output of U107 controls the automatic retransmission of serial data. Stand-alone and master units assert RTS to gate the TXDATA output of U107 through an AND gate and via U125 onto the TXDATA pin of the master/slave interface. Relay K101 is energized when power is applied to the Model 708A.

Slave units negate RTS except when responding to a request by the master for setup or status information. A negated RTS signal blocks the TXDATA signal at its corresponding U128 AND gate. Incoming serial data to the RXDATA input of U107 is also routed through a U128 gate, the U125 OR gate, and onto the master/slave TXDATA pin to effect the automatic retransmission.

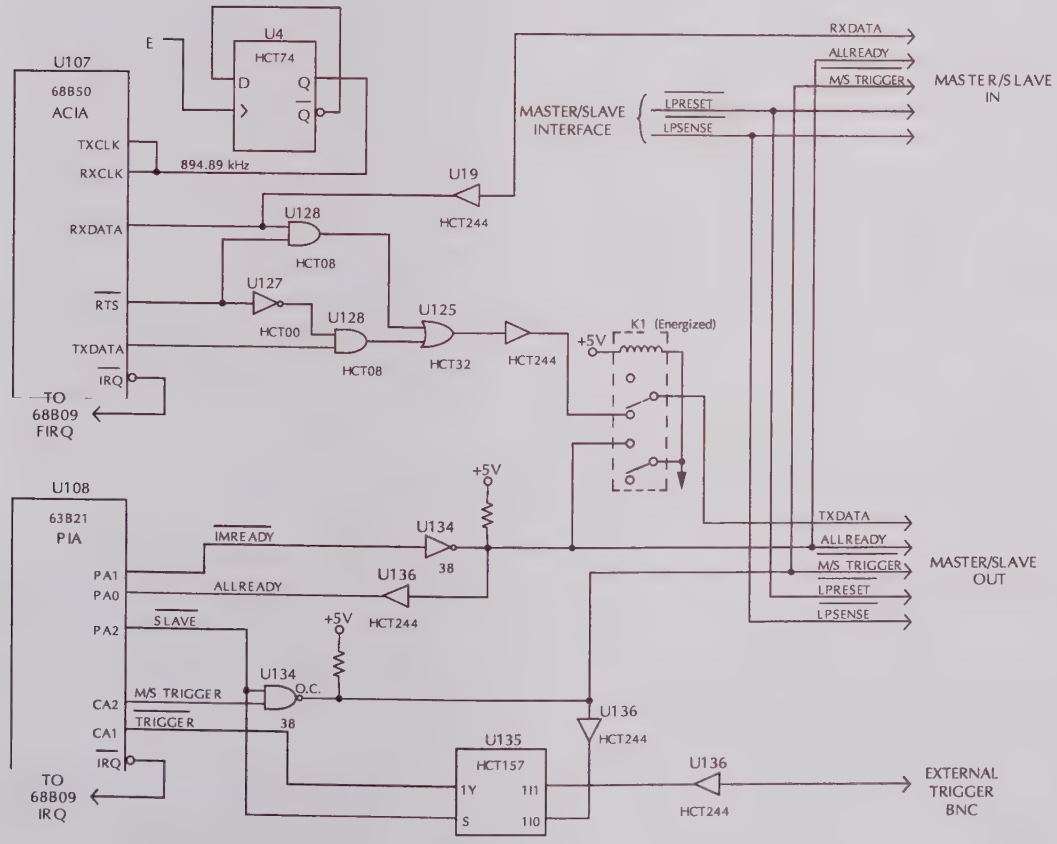


Figure 6-11
Master/slave interface simplified schematic

6.7.2 Control signals

Bused control signals are managed by U108 (63B21 PIA). Bused outputs are driven by U134 (7438 open-collector NAND) and are buffered for input with U136 receivers.

The SLAVE (low true) signal selects the external trigger source.

In slave units, the SLAVE signal is asserted. This causes multiplexer U135 to select the M/S TRIGGER (low true) signal for the trigger interrupt. Slaves are disabled from driving the M/S TRIGGER signal by the U134 NAND.

In master or stand-alone units, SLAVE is negated, and multiplexer U135 selects the External Trigger Input BNC for the trigger interrupt. This also enables the unit to drive the M/S TRIGGER signal via the U134 NAND.

The ALLREADY signal is wired -ORed so that it is negated whenever any unit in the master/slave loop has negated its IMREADY (low true) signal when receiving and processing data. When a slave unit is powered down, relay K101 provides a path to digital ground, simulating a negated IMREADY signal. This provides positive indication to other units on the master/slave loop that one of the units is not running. Power-up software waits until all units have asserted their IMREADY signal.

Assertion of M/S TRIGGER when the ALLREADY signal is false causes the slave units to reset to a known state. Asserting M/S TRIGGER with ALLREADY true triggers the slaves.

6.8 Digital I/O

The digital input and digital output ports are two separate interfaces contained on separate DB25 connectors. A simplified schematic of the circuitry is shown in Figure 6-12.

Digital inputs are managed by U132 and U133 (74HCT373 transparent latch), which is decoded as a port on the microprocessor bus by PAL U116. U133 latches in the states of lines IN(0:7), and U132 latches in the states of IN(8:15) when the microprocessor reads the digital input port.

Digital outputs are managed by U118 and U119.

6.9 IEEE-488 bus interface

The Model 708A has an IEEE-488 standard interface that allows the instrument to be programmed from a system controller. Commands can be sent over the bus to the instrument, and data can be requested from the instrument.

The IEEE-488 interface is made up of U109, U110, and U112. U109 is a 9914A GPIA (general purpose interface adapter), while U110 and U112 are interface bus drivers.

The GPIA simplifies microprocessor interfacing to the IEEE-488 bus because many control sequences take place automatically. For example, when the microprocessor writes to the GPIA data output register, the handshake sequence is performed automatically. Without the GPIA chip, complex microprocessor routines would be required.

On the microprocessor side of the GPIA, data transmission is handled much like any other data bus transaction. Microprocessor data access is performed through the D0-D7 lines, while A0-A2 (the three least significant address lines) select among the 14 internal registers (seven read, seven write) of the GPIA. Chip selection is performed by the SELECT 9914 line.

The output of the GPIA is in standard IEEE-488 format. All of these lines are active low with approximately zero volts representing a logic one:

- Eight data lines (D1-D8).
- Three handshake lines (DAV, NRFD, NDAC).
- Five management lines (ATN, REN, IFC, SRQ, EOI).

The two IEEE-488 bus drivers, U110 and U112, bring the drive capability of the interface up to the requirements of the IEEE-488 standard, which includes provisions for up to 15 devices on the bus at once. The outputs of the bus drivers are connected to J1011, a standard IEEE-488 connector.

6.10 Power supplies

The major component of the power supply is a universal AC-input switching power supply. This supply contains an internal in-line fuse and an autoranging input, which automatically adjusts to the voltage of the input mains. The power switch is located on the display board and is actuated through a mechanical extension of the POWER button. The AC input is also wired to the display board.

The switching power supply provides regulated +6VDC for the relay power circuitry. These voltages are routed to the switch card via the digital board and backplane. On the digital board, the +6V is regulated to +5V using one LM2940 regulator. The LM2940 supplies +5V to the display, digital circuitry, backplane, switch cards, and micro-DIN connections.

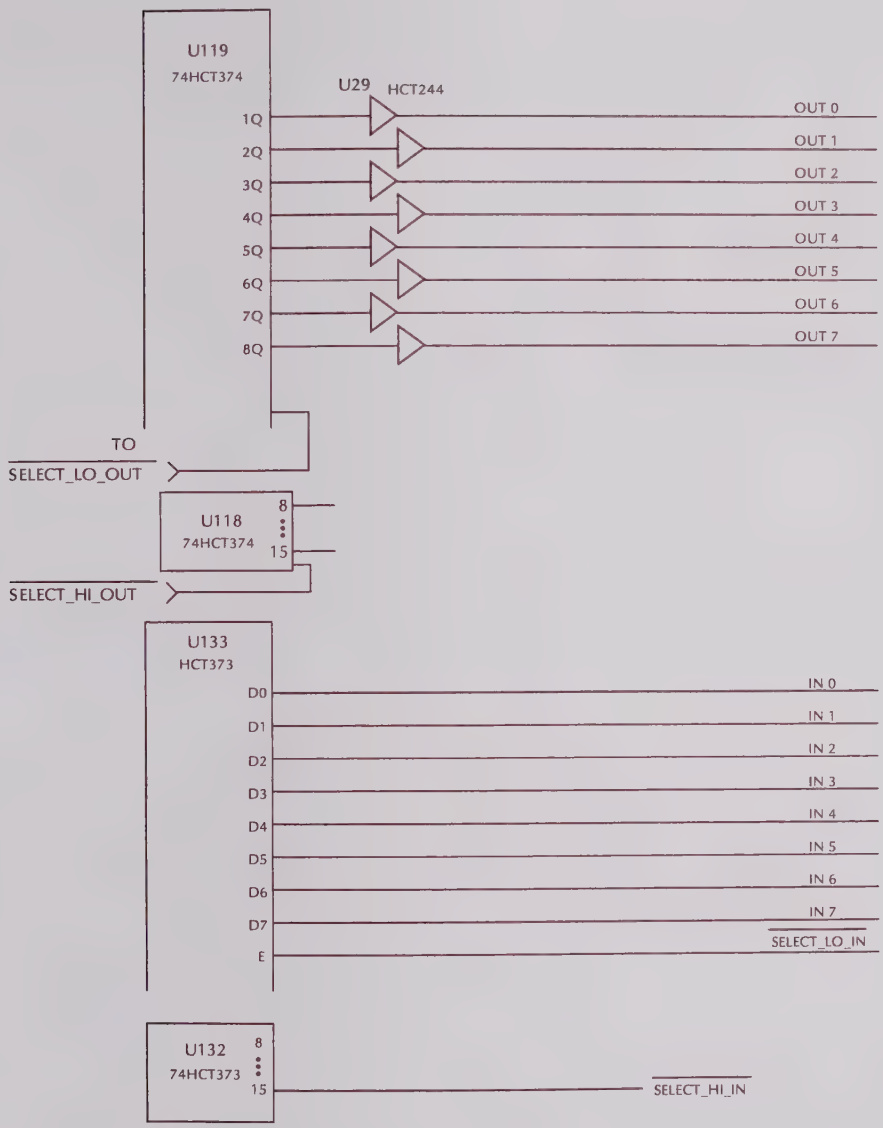


Figure 6-12
Digital I/O interface simplified schematic

7

Maintenance

7.1 Introduction

This section contains information necessary to maintain and troubleshoot the Model 708A Switching System. Handling and cleaning procedures are also included.

WARNING

The servicing procedures in this section are intended for qualified electronics service personnel only. Do not attempt to perform these procedures unless you are qualified to do so. Some of the procedures may expose you to potentially lethal voltages (>30V RMS) that could result in personal injury or death if normal safety precautions are not observed.

7.2 Fixed rack installation

Refer to Section 8 for a complete list of the necessary hardware for a fixed mounting (rack mounting parts) of a Model 708A in a 19 inch wide rack (24 to 30 inches deep). The parts are included with each Model 708A Switching System order. Verify that all parts are available before beginning the installation procedure.

1. Select a position in the rack (Figure 7-1). The Model 708A will take up about 3½ inches of vertical space. Using one of the dress panels (Item A), place it in the rack at the desired location. Line up the two slotted holes in the dress panel with the corresponding front rack flange holes. Mark the position of each rack hole.

NOTE

The mainframe must be mounted at a height that is an increment of 1¾ inches from the top or bottom of the rack. Attempting to mount the switching system at a non-incremental height will lead to difficulties with hole alignment.

2. Referring to Figure 7-1 and the marked rack holes (step 1), slide two nuts (Item C) on each front rack flange. Align holes for nuts with holes of rack flange.
3. Attach the handles (Item B) to the dress panels with four flathead screws (Item E).
4. Attach the dress panels (Item A) to the Model 708A Switching Matrix with screws (Item F).
5. Remove feet from bottom of Model 708A Switching System. Retain for future use the nut bar to each rear rack flange with two binder head screws. Grasping the Model 708A by its handles, insert it into the prepared space in the rack.
6. Secure the Model 708A Switching System to the front rack flanges with screws (Item D).

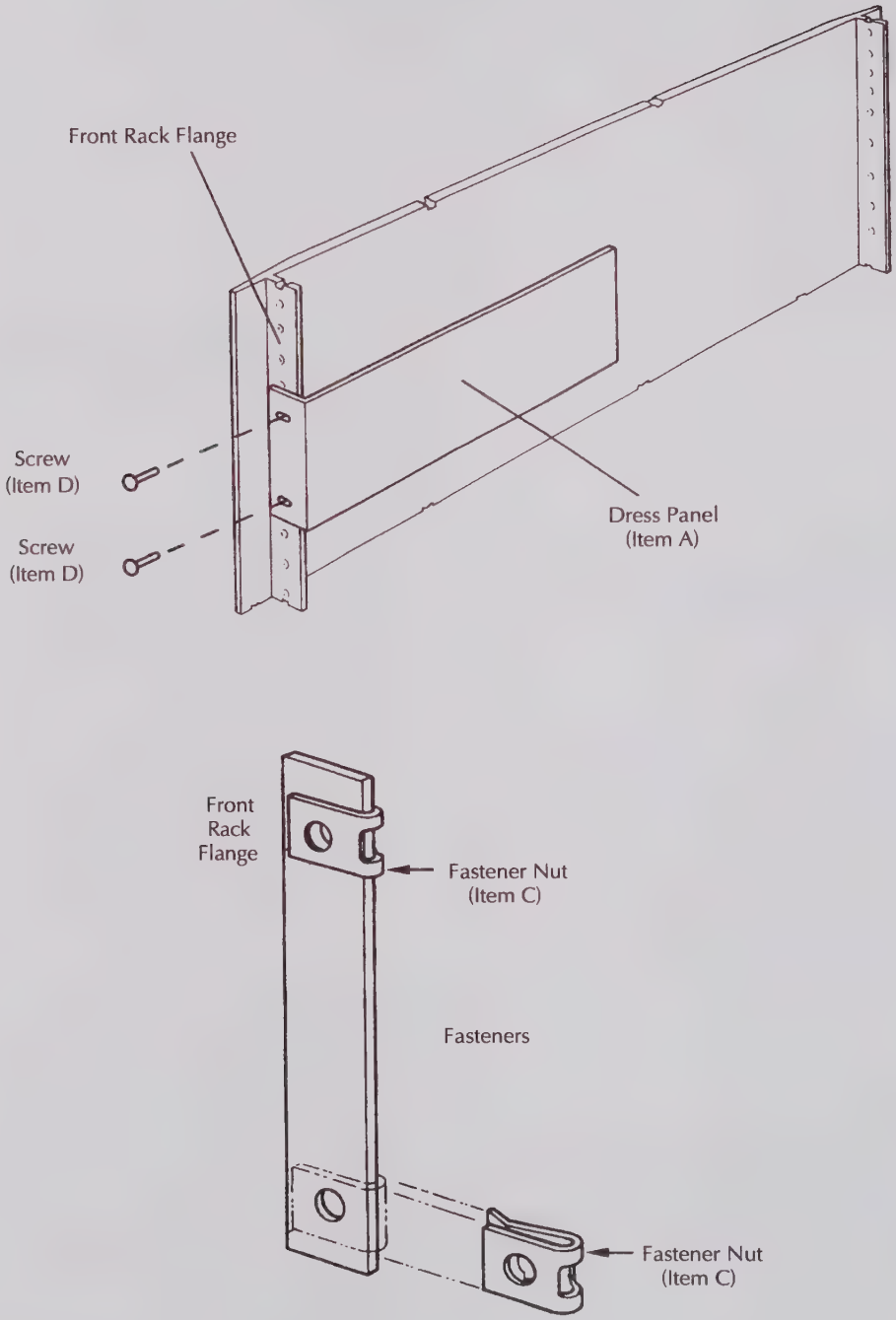


Figure 7-1
Rack installation

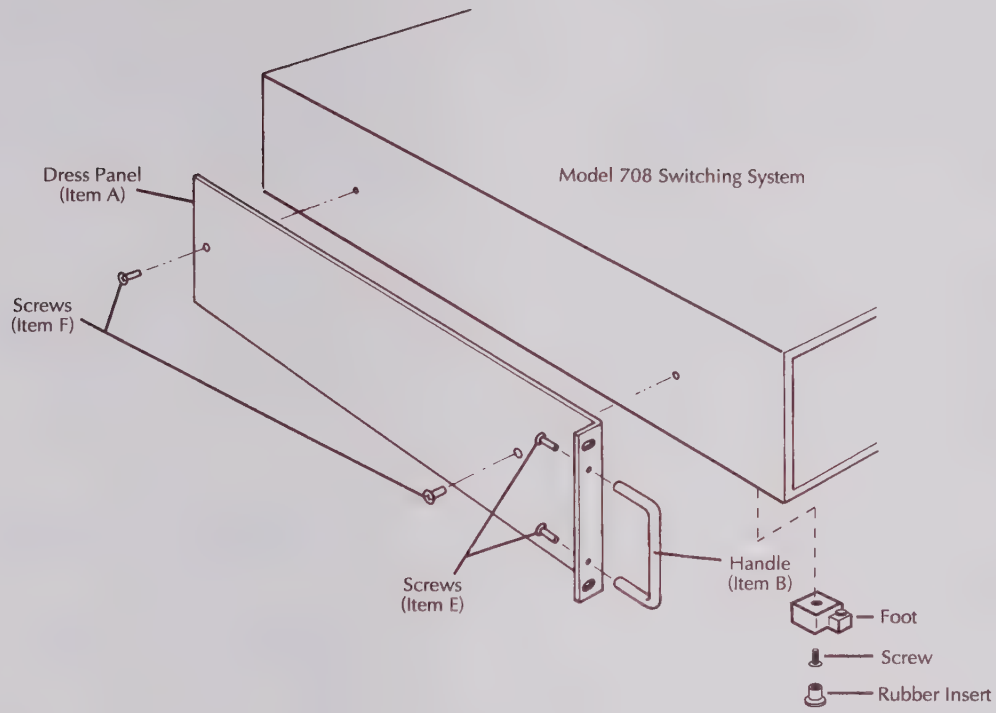


Figure 7-1 (cont.)
Rack installation

7.3 Cover removal

WARNING

Disconnect the instrument from the power line and other equipment before replacing the fuse.

1. Turn off the Model 708A Switching System. Disconnect the instrument from the power line and other equipment.
2. Remove the Model 708A from the rack (if rack mounted). Place it in a suitable location for disassembly.
3. Remove screws (1) and dress panel (2) from the switching system (Figure 7-2).
4. Remove screws (3) and top cover (4) from the switching system.
5. Gently pry off the top cover of the switching system. Refer to paragraph 7.10 before handling or removing internal components of the Model 708A Switching System.

7.4 Fuse/power supply replacement

The line fuse, which is mounted on the power supply, protects the instrument's power line input. If the fuse needs to be replaced, the power supply must be replaced as well. Use the following procedure to replace the power supply. Also refer to assembly drawings 708A-050 and 708A-051 at the end of this section.

WARNING

Disconnect the instrument from the power line and other equipment before replacing the power supply.

Procedure

1. Turn off the Model 708A Switching System. Disconnect the instrument from the power line and other equipment.
2. Remove the instrument's cover (paragraph 7.3). The power supply is located under a plastic safety cover.
3. Remove the AC input and DC output connectors from the power supply.
4. Remove the four mounting screws and lift out the power supply.
5. Replace the power supply (Keithley part number PS-66), attach it with four screws, and reconnect the input and output connectors.
6. Reinstall the cover (paragraph 7.3).

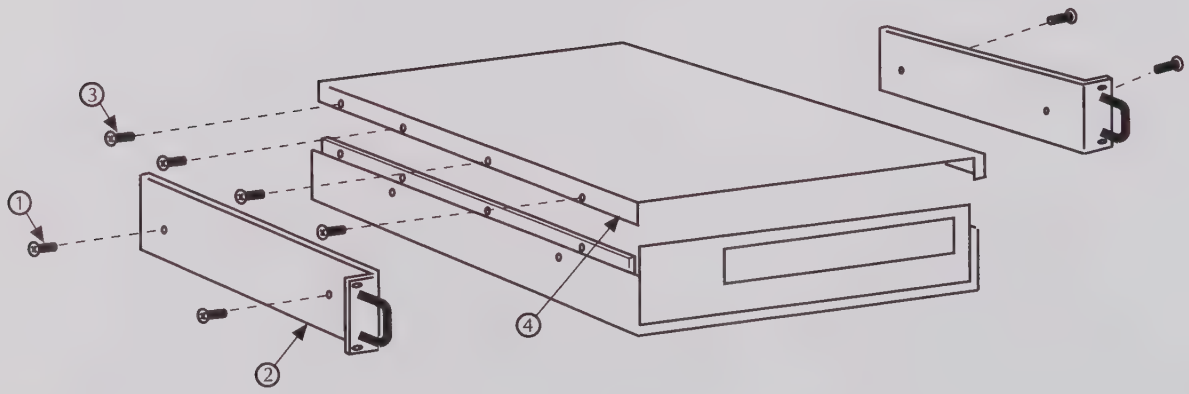


Figure 7-2
Screw and dress panel removal

7.5 Battery replacement

When line power to the Model 708A is turned off, the lithium battery on the mother board provides backup power to the memory in which setups and parameters are stored. The battery has enough capacity to maintain data for one year of continuous power off, or two years if the Model 708A is powered on for 12 hours each day. The battery by itself has a shelf life of eight years.

The battery may be replaced with any CR2450 lithium coin cell. It can also be ordered from Keithley Instruments (part number BA-44), as discussed in Section 8 of this manual.

Replacement of the lithium battery is normally a safe procedure as long as the following safety precautions are followed.

WARNING

The precautions below must be followed to avoid possible personal injury.

1. **Wear safety glasses or goggles when working with lithium batteries.**
2. **Do not short the battery terminals together.**
3. **Do not incinerate or otherwise expose the batteries to excessive heat (>60°C).**
4. **Keep lithium batteries away from all liquids.**
5. **Do not recharge lithium batteries.**
6. **Observe proper polarity when inserting battery into holder.**
7. **Bulk quantities of lithium batteries should be disposed of as hazardous waste. Single batteries should be thrown in the trash.**

Replace the battery as follows:

1. Turn off the Model 708A Switching System. Disconnect the instrument from the power line and other equipment.
2. Remove the cover (paragraph 7.3).
3. Remove the shield. (Refer to assembly drawing 708A-051 at the end of this section.)
4. The lithium battery is on the mother board. (Refer to component layout 708A-100 at the end of Section 8.) Pry the battery out of its holder using a non-metallic tool.

WARNING

Do not use a metal tool to pry out the battery, because you could short its terminals.

5. Install the new battery. Be sure to observe proper polarity as stamped on the battery holder.
6. Install the shield.
7. Install the cover (paragraph 7.3).
8. Reinstall the power line cord and turn on the Model 708A. It will power up in random conditions.
9. Use the R0 command (paragraph 5.9.17) to restore factory default conditions.

7.6 Digital I/O power selection (jumper W101)

Jumper W101 is used to select between the internal and external power supply. The factory setting is for the internal (5V) power supply. When supplying external power, make sure the supply conforms to the specifications listed at the front of this manual.

1. Turn off the Model 708A Switching System. Disconnect the instrument from the power line and other equipment.
2. Remove the cover (paragraph 7.3).
3. Remove the shield. (Refer to assembly drawing 708A-051 at the end of this section.)
4. Set the position of jumper W101 to internal or external (refer to Figure 7-3).
5. Replace the shield.
6. Install the cover (paragraph 7.3).
7. Reinstall the power line cord and turn on the Model 708A.

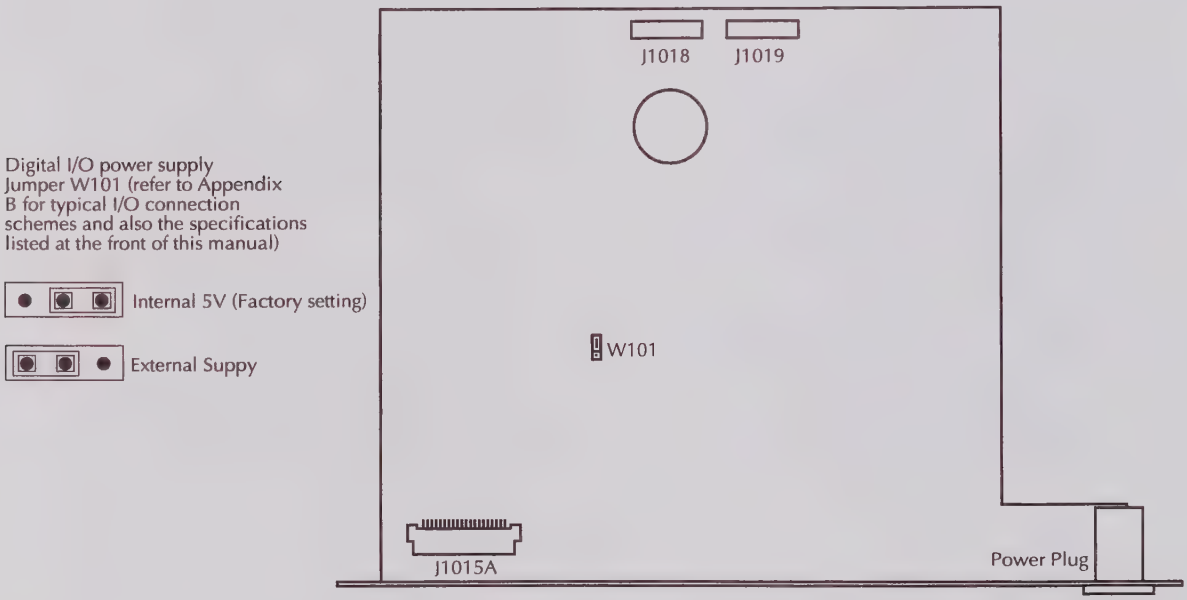

Digital I/O power supply
Jumper W101 (refer to Appendix B for typical I/O connection schemes and also the specifications listed at the front of this manual)
Internal 5V (Factory setting)
External Suppy
J1018
J1019
W101
J1015A
Power Plug

Figure 7-3
W101 jumper location

7.7 Disassembly

If it is necessary to troubleshoot the instrument or replace a component, use the following disassembly procedure. Also refer to the assembly drawings at the end of this section:

- 708A-030 — Panel assembly
- 708A-040 — Front panel assembly
- 708A-050 — Bottom cover assembly
- 708A-051 — Chassis assembly
- 708A-080 — Final inspection

WARNING

Before disassembly, disconnect the line cord, ensure no voltage is applied from user circuits, and remove all plug-in cards from the instrument.

1. Turn off the Model 708A Switching System. Disconnect the instrument from the power line and other equipment.
2. Remove the analog backplane or switching card that may be installed (refer to paragraph 2.2 for an analog backplane or paragraph 2.3 for a card).
3. Remove the cover (paragraph 7.3).
4. Remove the shield (708A-051).
5. Remove the desired component board from the Model 708A by disconnecting all plugs and cables from the board and removing necessary hardware.
6. Reverse the above procedure to assemble the instrument.

7.8 Static sensitive devices

CMOS devices are designed to operate at high impedance levels for lower power consumption. As a result, any static charge that builds up on your person or clothing may be sufficient to destroy these devices if they are not handled properly. Use the following precautions when handling static sensitive devices.

NOTE

Since the CMOS devices installed in the Model 708A are not denoted in this manual, all ICs and transistors should be handled as static sensitive devices.

1. Transport static-sensitive devices in containers designed to prevent static build-up. Typically, these parts will be received in anti-static containers of plastic or foam. Always leave the devices in their original containers until ready for installation.
2. Remove the devices from their protective containers only at a properly grounded work station. Also ground yourself with a suitable wrist strap.
3. Handle the devices only by the body; do not touch the pins or terminals.
4. Any printed circuit board into which the device is to be inserted must also be properly grounded to the bench or table.
5. Use only anti-static type de-soldering tools.
6. Use only soldering irons with properly grounded tips.
7. Once the device is installed on the PC board, it is usually adequately protected, and normal handling can resume.

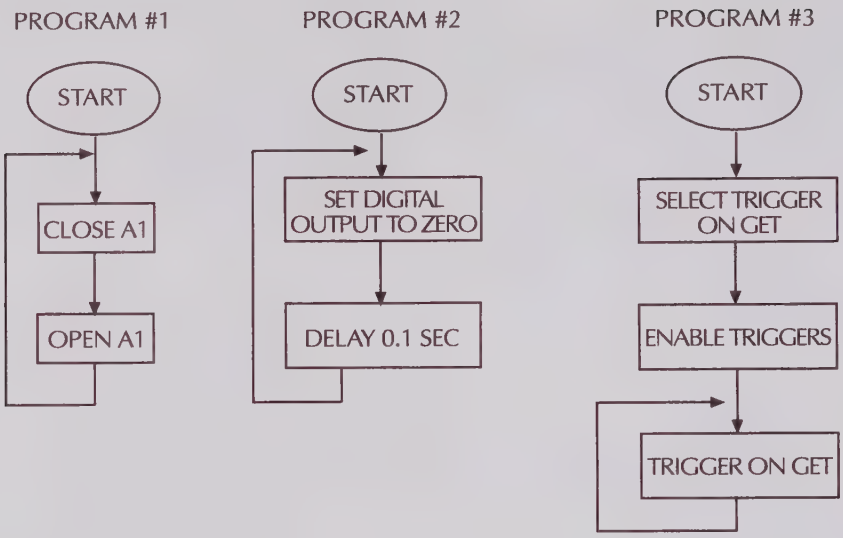


Figure 7-4
Troubleshooting programs

7.9 Switching system troubleshooting

This troubleshooting information is intended for qualified personnel having a basic understanding of digital and analog circuitry. The individual should also be experienced at using common test equipment, as well as ordinary troubleshooting procedures. The information has been written to assist in isolating a defective circuit or circuit section. Isolation of the specific component is left to the technician.

Note that component layout drawings are located at the end of Section 8. Refer to Section 6 for an overview of operating principles.

7.9.1 Recommended test equipment

Table 7-1 lists the minimum recommended equipment for troubleshooting. Other equipment, such as logic analyzers, could also be helpful.

Table 7-1
Recommended troubleshooting equipment

Description	Application
DMM (Keithley Model 2000)	Measure dc voltage
Dual-trace, triggered sweep oscilloscope, DC to 50MHz	Check clock and logic pulses.

7.9.2 Power-up self-test

As described in Section 4, the Model 708A performs a series of tests on power-up. Individual tests in this series that can be used for troubleshooting a Model 708A include:

ROM test — A checksum test of the ROM. Test failure is indicated by a ROM Fail error condition.

RAM test — A read/write test of battery backed-up CMOS RAM. Test failure is indicated by a RAM Fail error condition.

Display test — A visual test of the front panel displays (visual check for all LEDs and indicators being lit).

Perform the tests over the IEEE-488 bus with the J0 command (paragraph 5.9.9).

7.9.3 Power supply checks

The Model 708A Switching System power supply will resist problems affecting conventional power supplies. The power supply automatically adjusts to a broad range of mains voltage (100-240VAC) and frequencies (50-60Hz), so the fuse should not fail because of an incorrect mains voltage.

If the power supply fails, the instrument will be inoperative. Power supply input and output voltages may be checked at the connectors at each end of the board.

Table 7-2 lists the output voltages that should be checked.

NOTE

Programming the 99-IEEE switch set for 99 will turn all LEDs on.

7.9.4 Mother board checks

The procedures to check circuitry on the mother board, including the microcomputer, relay control circuitry, display interface, and digital I/O port, are located in Table 7-4 through Table 7-6.

Procedures for testing the light pen and master/slave interface options are listed in Table 7-7 and Table 7-8.

The waveforms described in the troubleshooting tables are present with power-up default conditions (idle state), unless otherwise indicated. To view some of the waveforms, run a program loop. Refer to the troubleshooting programs in Figure 7-4.

NOTE

If the ROM (U105) must be replaced for any reason, restore the Model 708A to factory default conditions with the device-dependent command R0 (paragraph 5.9.17).

Table 7-2
Power supply checks

Test point	Output voltage	Tolerance	Ripple/noise
J102-1 (Referenced to J102-2)	+12.0VDC	±10%	120mV
J102-4 (Referenced to J102-3, as adjustable)	+6.0VDC	±2%	50mV

Table 7-3
Microcomputer checks

Step	Item/ component	Signal	Comments
1	U101 pin 3	5VDC ±5% (0.5V)	
The following mother board signals are referenced to digital common.			
2	U104 pin 37	MPU Reset	Stays low (110-260ms on power-up), then goes high.
3	U104 pin 34	E clock	1.79MHz square wave for peripheral chips.
4	U103 pin 23	SELECT VIA	Low going pulses (1kHz).
5	U104 pins 8-23	Address bus (A0-A15)	Check for stuck bit.
6	U104 pins 24-31	Data bus (D0-D7)	Check for stuck bit.

Table 7-4
Relay control checks

Step	Item/component	Signal	Comments
1	U103 pin 23	SELECT VIA	Low going pulses (1kHz).
2	U137 pin 5	CLRADDR	High logic pulse at start of each matrix card ID byte transfer sequence on power-up.
3	U137 pin 3	NEXTADDR	Low logic pulse before each byte transfer from matrix card on power-up.
4	U137 pin 6	IDDATA	Matrix card ID logic pulse train on power-up.
5	U130 pin 1	SELECT RELAYDATA	Low going pulse when program #1 is running.
6	U137 pin 7	CLK	Eight low-going pulses (1.79MHz square wave) after each SELECT RELAYDATA pulse.
7	U137 pin 18	RELAYDATA	Logic pulses to load relay drivers on matrix card.

Note: See Figure 7-5 for waveforms of steps 5 through 7.

Table 7-5
Display interface checks

Step	Item/component	Signal	Comments
1	U103 pin 23	SELECT VIA	Low going pulses (1kHz).
2	U103 pin 18	FPCLK	Base frequency of 895kHz with ten sets of pulses every 1ms.
3	U125 pin 6	DISPCLK	Base frequency of 895kHz with nine sets of pulses every 1ms.
4	U125 pin 3	KEYCLK	Base frequency of 895kHz with one set of pulses every 1ms.
5	U126 pin 6	DISPDATA	See Figure 7-6.
6	U126 pin 2	KEYDATA	See Figure 7-6.

Table 7-6
Digital I/O checks

Step	Item/component	Signal	Comments
The following mother board signals are referenced to digital common.			
1	U108 pin 23	SELECT_PIA	Low going pulses (1kHz).
2	U108 pins 10-17	SW(0-7)	Logic low when programmed low.
3	U133 pin 1	SELECT_LO_INPUT	Low going pulses (5kHz) when digital input is displayed.
4	U133 pins 3, 4, 7, 8, 13, 14, 17, 18	LO_IN(0-7)	Logic high when port disconnected.
5	U1119 pin 11	SELECT_LO_OUT	Pair of low going pulse trains when digital output is displayed.
6	U119 pins 2, 5, 6, 9, 12, 15, 16, 19	LO_OUT(0-7)	Low logic pulse selects card for data transfer sequence.

Table 7-7
Light pen checks

Step	Item/component	Signal	Comments
The following mother board signals are referenced to digital common.			
1	U103 pin 23	SELECT VIA	Low going pulses (1kHz).
2	U126 pin 12	SENSEPULSE	Low going pulse (15µsec) when light pen is pointed at lit LED.
3	U126 pin 9	LPSWITCH	Low logic level when light pen button is pressed.
4	U103 pin 17	LPSENSE	High going pulse when light pen button is pressed and pen is pointed at an LED.
5	U103 pin 39	LPRESET	Multiple high going pulses when light pen button is pressed.

Table 7-8
Master/slave checks

Step	Item/component	Signal	Comments
The following mother board signals are referenced to digital common. When troubleshooting a single unit, loop a cable from Master/Slave Out to Master/Slave In of the same unit, and then program unit as master.			
1	U107 pins 3,4	RXCLK, TXCLK	895kHz square wave.
2	U107 pin 9	SELECT ACIA	Low going pulses with manual triggers.
3	U107 pins 2,6	RXDATA, TXDATA	Low going pulse pair with manual trigger.
4	U107 pin 7	FIRQ	Low going pulse with manual trigger.
5	U108 pin 23	SELECT PIA	Low going pulses (1kHz).
6	U108 pin 39	M/S TRIGGER	High going pulses when program #3 is running. (Triggering stops when Relay Step equals 100.)

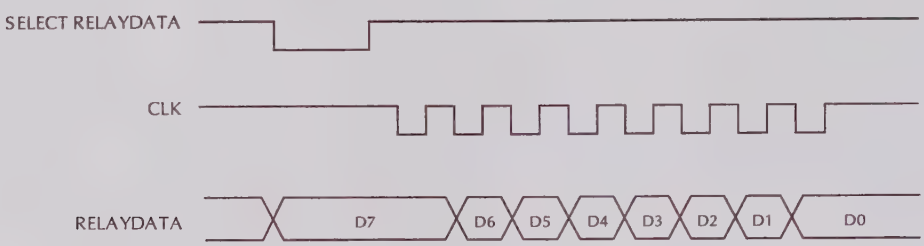


Figure 7-5
Relay control waveforms

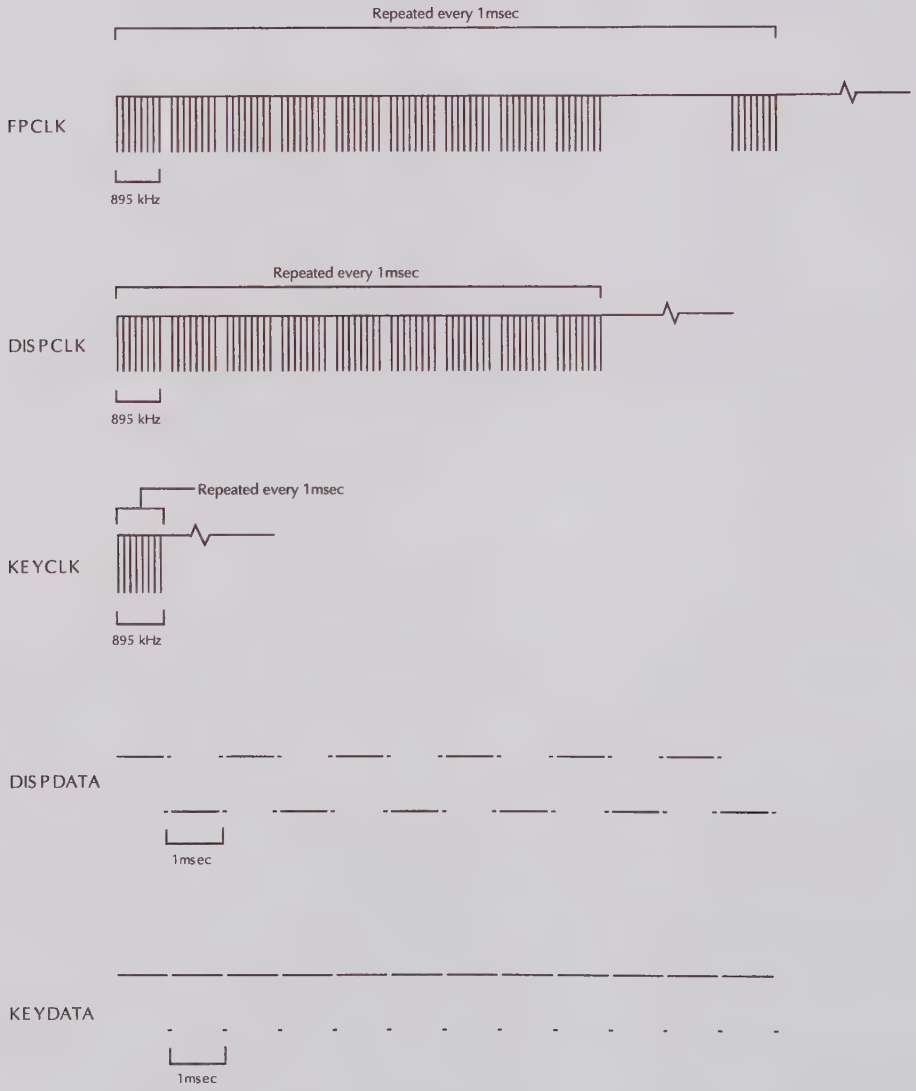


Figure 7-6
Display interface waveforms

7.9.5 Display checks

To troubleshoot the display board, disassemble it from the front panel, and then reconnect the power cable and ribbon cable with the display board on a bench.

A troubleshooting procedure is outlined in Table 7-9.

7.9.6 Using an extender card

To access circuitry on the plug-in relay cards of the Model 708A, use a Model 7070 Universal Adapter Card. The Model 7070 must be configured as an extender card by placing the configuration jumper in the EXTEND position. See the Model 7070 Instruction Manual for complete details on using the card.

7.10 Handling and cleaning

Since matrix card rows are extended on the analog backplane of the Model 708A, a contaminated backplane will degrade card isolation specifications. If an isolation problem exists, the backplane should be cleaned.

The following procedure describes how to clean high impedance PC boards, such as the Model 708A backplane, but it can be used to clean all PC boards. To remove the backplane, refer to paragraph 2.2.

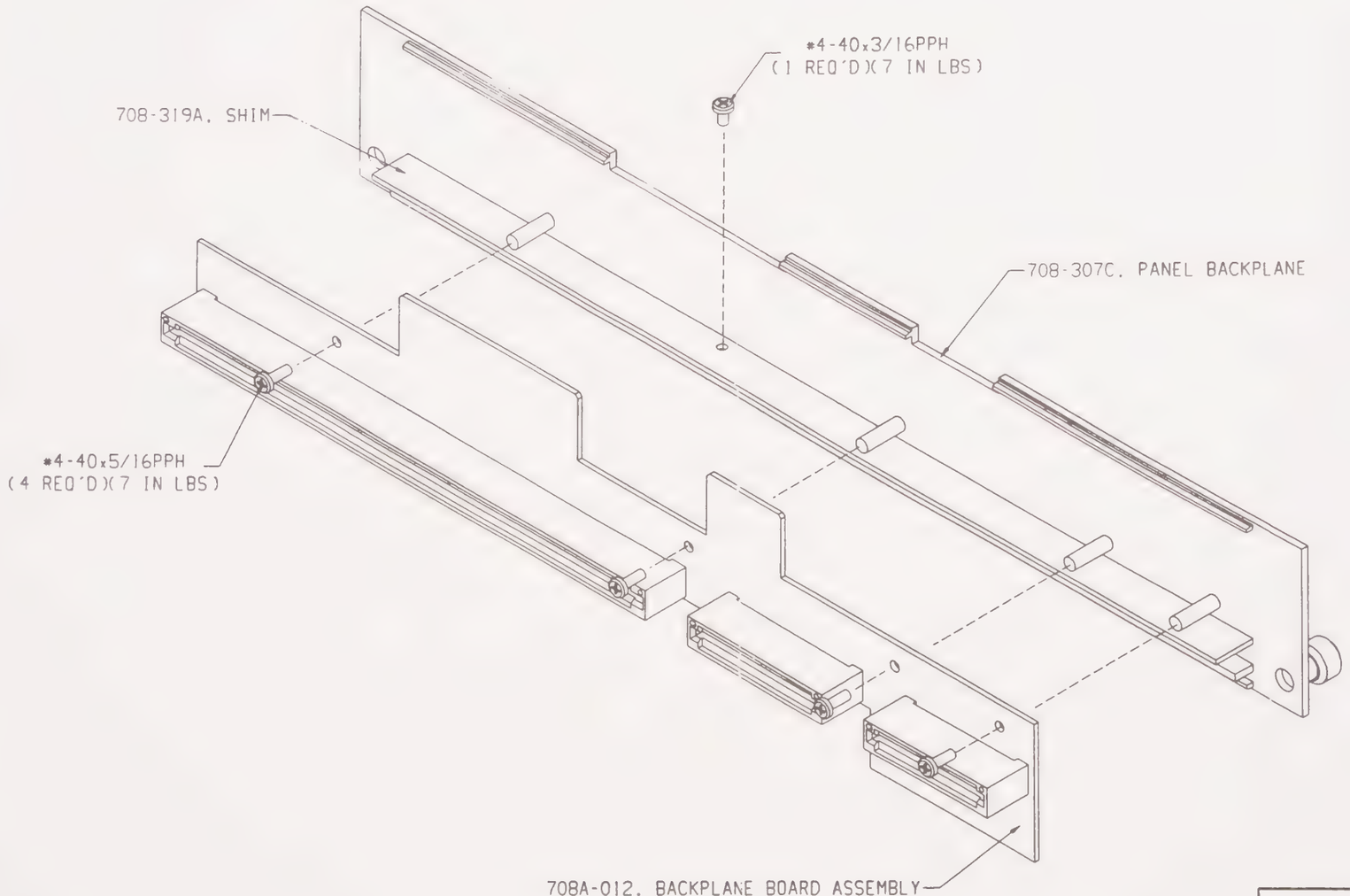
1. Handle the board by the edges only. Do not touch any board surfaces. When servicing, wear clean, white cotton gloves.
2. If making solder repairs on the board, use a flux that is rosin RMA based. Remove the flux from these areas when the repair is complete. Use methanol and clean cotton swabs to remove the flux. Take care not to spread the flux to other areas of the board.
3. Once the flux has been removed, swab only the repaired area with methanol, and then blow-dry the board with dry nitrogen gas.
4. After cleaning, the board should be placed in a 50°C low humidity environment for several hours.

Table 7-9
Display board checks

Step	Item/component	Signal	Comments
The following display board signals are referenced to digital common. When troubleshooting the LED array, check for these signals when the LED is lit (e.g., crosspoint A1).			
1	U204 pin 12	Source driver	Card row A - Logic high for 9ms.
2	U205 pin 17	Sink driver	Card column 1 - Logic low.
	Front panel buttons:		
3	U207 pins 1, 5, 6	Button columns	Logic high with a low going 1ms pulse.
4	U137 pins 3-5, 11-14	Button rows	Logic high with a low going 1ms pulse when button is pressed.

NO. 708A-030

LTR	ECA NO.	REVISION	ENG	DATE
A	21847	Released	SF	7/28/98



PART NUMBER	QTY	DESCRIPTION
708A-012	1	BACKPLANE BOARD ASSEMBLY
708A-307C	1	PANEL BACKPLANE
*4-40x5/16PPH	4	PHIL PAN HEAD SCREW
*4-40x3/16PPH	1	PHIL PAN HEAD SCREW
708-319A	1	SHIM

708A	708A-051	Chassis Assembly	1
MODEL	NEXT ASSEMBLY	NEXT PROCESS STEP	QTY
USED ON			

DO NOT SCALE THIS DRAWING

KEITHLEY Keithley Instruments Inc. Cleveland, Ohio 44139

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

XX • ±.015 ANG • ±1°

XXX • ±.005 FRAC • ±1/64

SURFACE MAX 63

DATE 7/7/98 DRN Mat

SCALE X ENG APPR

MATERIAL

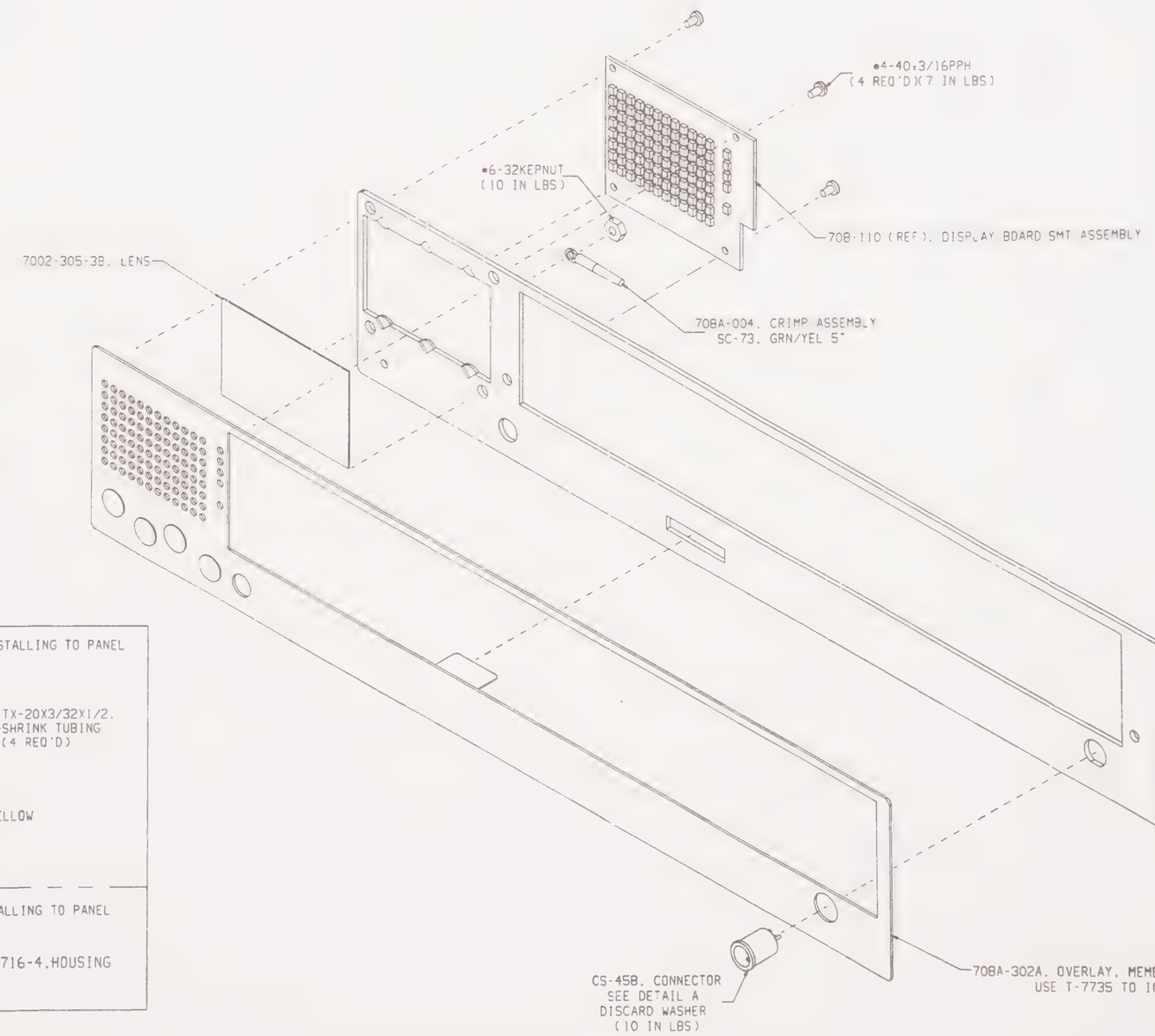
FINISH

TITLE Panel Assembly

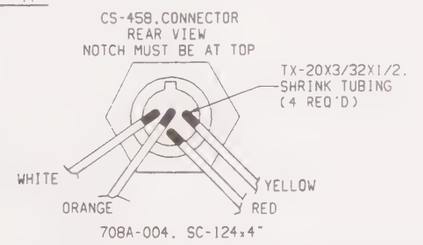
B NO. 708A-030

NO. 708A-040

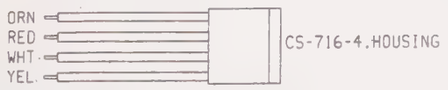
LTR	ECA NO.	REVISION	ENG	DATE
A	21847	Released	SF	7/28/98



DETAIL "A" WIRE CONNECTOR BEFORE INSTALLING TO PANEL



INSERT WIRES TO HOUSING AFTER INSTALLING TO PANEL



PART NUMBER	QTY	DESCRIPTION
708A-004	1	CRIMP ASSEMBLY
708-110 (REF)	1	DISPLAY BOARD SMT ASSEMBLY
708-301B	1	FRONT PANEL
708A-302A	1	OVERLAY. MEMBRANE SWITCH
7002-305-3B	1	LENS
CS-458	1	CONNECTOR
CS-716-4	1	CONNECTOR
•4-40x3/16PPH	4	PHIL PAN HEAD SCREW
•6-32KEPNUT	1	KEPNUT
TX-20x3/32x1/2	4	SHRINK TUBING
1/2THINLKWA	1	THIN LOCKWASHER

MODEL	NEXT ASSEMBLY	NEXT PROCESS STEP	QTY
708A	708A-050	Bottom Cover Assembly	1

USED ON

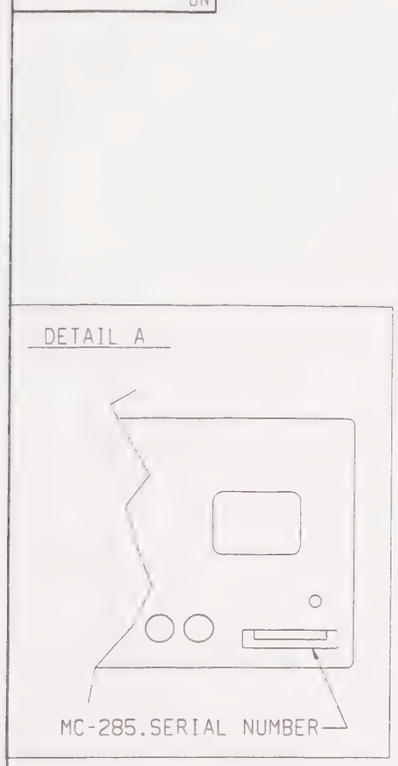
DO NOT SCALE THIS DRAWING	DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 7/7/98	SCALE 2/1
KEITHLEY Keithley Instruments, Inc. Cleveland, Ohio 44139	XX - ±.015 ANG - ±1°	DRN Mat	ENG APPR SF
	XXX - ±.005 FRAC - ±1/64	MATERIAL	
	SURFACE MAX 63	FINISH	

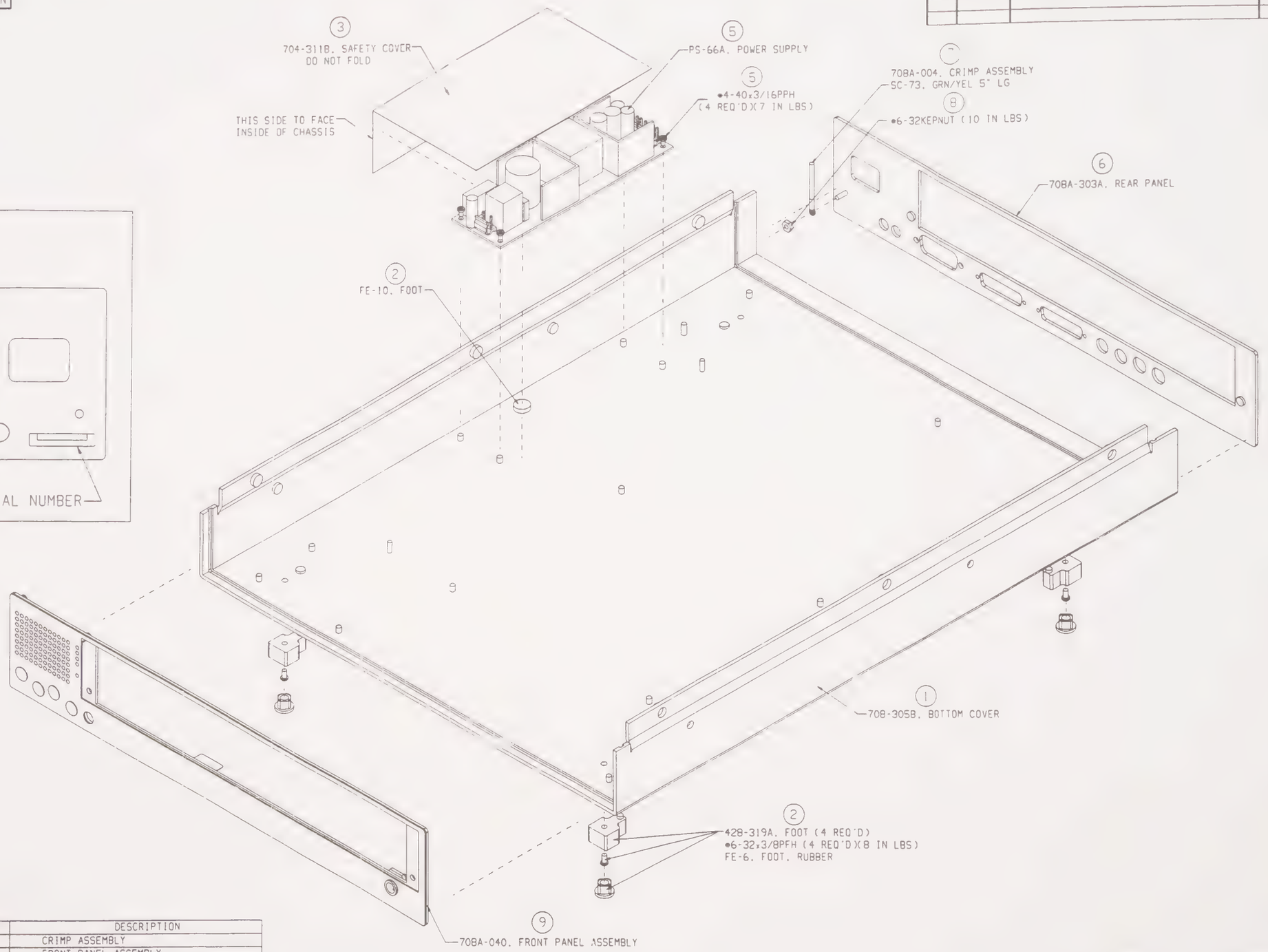
TITLE: Front Panel Assembly

C NO. 708A-040

NO. 708A-050

LTR	ECA NO.	REVISION	ENG	DATE
A	21847	Released	JH	7/28/98



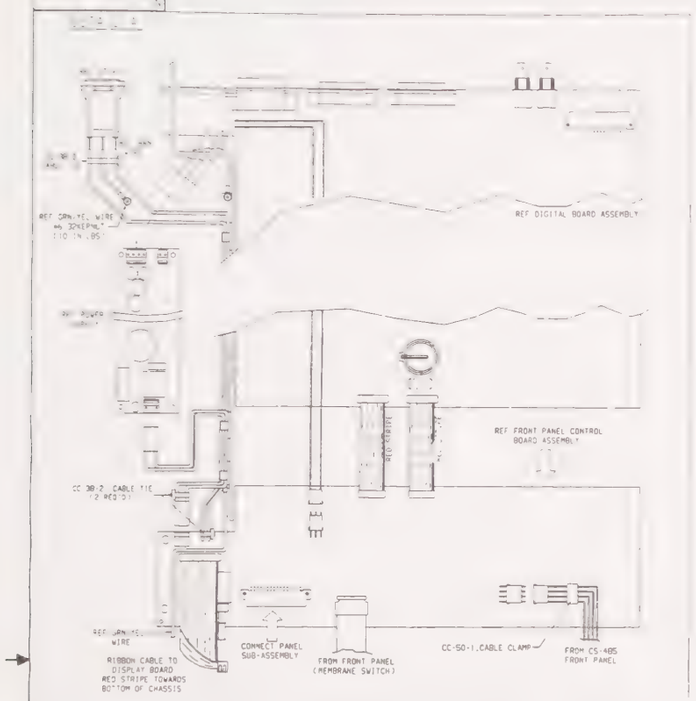


PART NUMBER	QTY	DESCRIPTION
708A-004	1	CRIMP ASSEMBLY
708A-040	1	FRONT PANEL ASSEMBLY
708A-303A	1	REAR PANEL
708-305B	1	BOTTOM COVER
FE-10	1	FOOT
PS-66A	1	POWER SUPPLY
•4-40x3/16PPH	4	PHIL PAN HEAD SCREW
•6-32KEPNUT	1	KEPNUT
MC-285	1	SERIAL NUMBER
428-319A	4	FOOT
FE-6	4	FOOT. RUBBER
•6-32x3/8PFH	4	PHIL FLAT HEAD SCREW
704-311B	1	SAFETY COVER

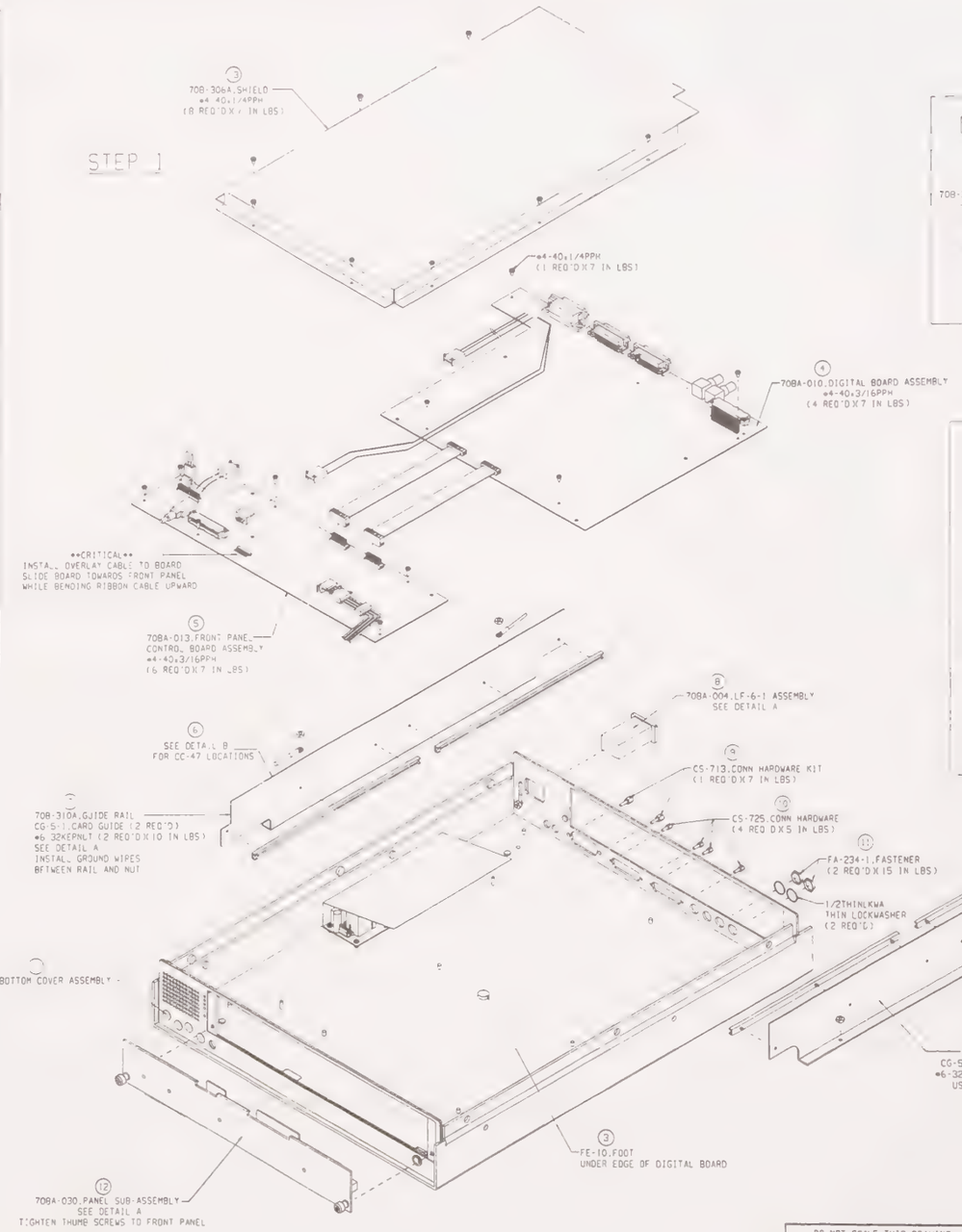
708A	708A-051	Chassis Assembly	1
MODEL	NEXT ASSEMBLY	NEXT PROCESS STEP	QTY
USED ON			

DO NOT SCALE THIS DRAWING	DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 7/7/98	SCALE 2/1	TITLE Bottom Cover Assembly
KEITHLEY Keithley Instruments Inc. Cleveland, Ohio 44139	XX ± .015 ANG ± 1°	DRN Mat	ENG APPR JH	
	XXX ± .005 FRAC ± 1/64	MATERIAL	C	NO. 708A-050
	SURFACE MAX 63	FINISH		

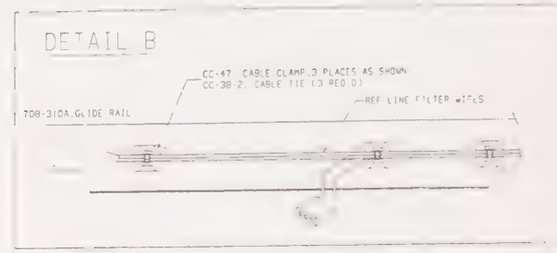
REV	ECN	DESCRIPTION	ENG	DATE
		Released		



STEP 1



DETAIL B



STEP 2

PART NUMBER	QTY	DESCRIPTION
708A-050	1	BOTTOM COVER ASSEMBLY
708A-030	1	PANEL SUB-ASSEMBLY
708A-004	1	CRIMP ASSEMBLY - (LF-6-1 ASSEMBLY)
708A-010	1	DIGITAL BOARD ASSEMBLY
708A-013	1	FRONT PANEL CONTROL BOARD ASSEMBLY
708-310A	2	GUIDE RAIL
25-5-	4	GUIDE RAIL
CC-50-1	1	CABLE CLAMP
CS-713	1	CONNECTOR HARDWARE KIT
CS-725	4	CONNECTOR HARDWARE
FA-234-1	2	FASTENER
2THINLKWA	2	THIN LOCKWASHER
FE-10	1	FOOT
#4-40,3/16PPH	10	PHIL PAN HEAD SCREW
#4-40,1/4PPH	9	PHIL PAN HEAD SCREW
#6-32KEPNUT	5	KEPNUT
708-306A	1	SHIELD
708-304A	1	TOP COVER
CC-38-2	5	CABLE TIE
CC-47	3	CABLE CLAMP

708A	708A-080	[illegible]	
MODEL	NEXT ASSEMBLY	NEXT PROCESS STEP	QTY
		CKT BD	

DO NOT SCALE THIS DRAWING	DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 7/8/98	SCALE NONE APPD	TITLE CHASSIS ASSEMBLY
KEITHLEY Keithley Instruments Inc. Cleveland, Ohio 44139	XX = ±.015 ANG = ±1°	DRN mgt		
	XXX = ±.005 FRAC = ±1/64	MATERIAL	D	NO. 708A-051
	SURFACE MAX 63	FINISH		

708A-080
NO.

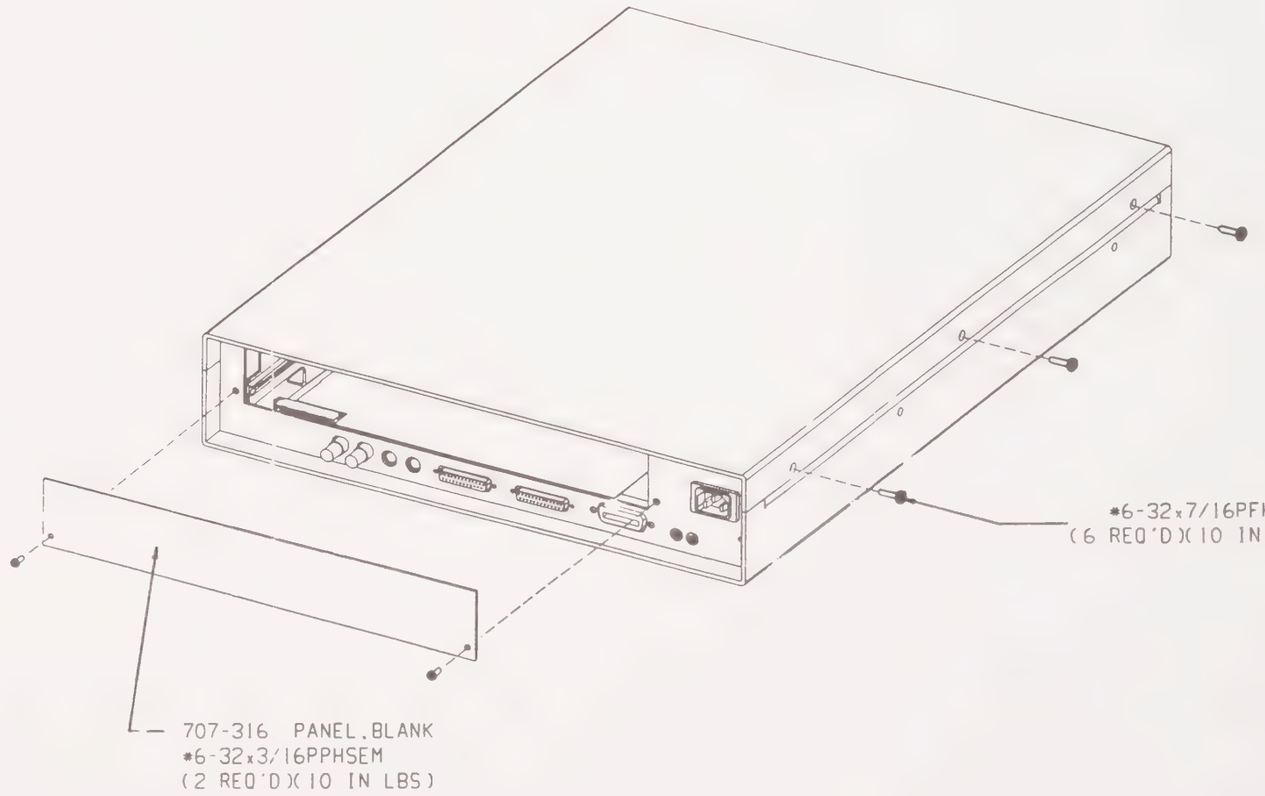
LTR	ECA NO.	REVISION	ENG	DATE
A	21647	Released	SF	7/28/98

WRITE MODEL NUMBER. SERIAL NUMBER.AND DATE ON CERTIFICATE OF CALIBRATION.

PLACE UNIT INTO CHIPLOC BAG AND SEND THE W.O. SHIPPING KIT ITEMS AND CALIBRATION REPORT WITH UNIT TO AUDIT.

PLACE MODEL NUMBER LABEL ON CHIPLOC BAG.

CALL STOCKROOM FOR WORK ORDER SHIPPING KIT BEFORE SENDING UNIT TO F.G.S.



PART NUMBER	QTY	DESCRIPTION
708A-051	1	CHASSIS ASSEMBLY
707-316	1	PANEL.BLANK
PA-214	1	CERTIFICATE OF CALIBRATION
*6-32x7/16PFH	6	PHIL FLAT HEAD SCREW
*6-32x3/16PPHSEM	2	PHIL PAN HEAD SEMS SCREW
PO-14-1	1	CHIPLOC BAG
708A-901-00*	1	MANUAL PACKAGE W.O. SHIPPING KIT
704-330A	1	BINDER W.O. SHIPPING KIT
708-318A	2	PANEL.DRESS W.O. SHIPPING KIT
CO-7	1	LINE CORD W.O. SHIPPING KIT
FA-130	4	FASTENER W.O. SHIPPING KIT
FA-244	4	FASTENER W.O. SHIPPING KIT
HH-31-1	2	HANDLE W.O. SHIPPING KIT
MC-650A	1	SPINE LABEL W.O. SHIPPING KIT
PO-14-5	2	CHIPLOC BAG W.O. SHIPPING KIT
*10-32x1/2PPHSEM	4	PHIL PAN HEAD SEMS SCREW W.O. SHIPPING KIT
*6-32x1/4PPH	4	PHIL PAN HEAD SCREW W.O. SHIPPING KIT
*8-32x3/8PFH	4	PHIL FLAT HEAD SCREW W.O. SHIPPING KIT

PERFORM HIPOT TEST PER MS-1537

708A	Audit	Audit	1
MODEL	NEXT ASSEMBLY	NEXT PROCESS STEP	QTY
USED ON			

DO NOT SCALE THIS DRAWING	DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 7/7/98	SCALE 2/1	TITLE FINAL INSPECTION
KEITHLEY Keithley Instruments Inc. Cleveland, Ohio 44139	XX • ±.015 ANG • ±1°	DRN mat	ENG APPR	
	XXX • ±.005 FRAC • ±1/64	MATERIAL	B	NO. 708A-080
	SURFACE MAX 63	FINISH		

8

Replaceable Parts

8.1 Introduction

This section contains replacement parts information and component layout drawings for the Model 708A.

8.2 Parts lists

The parts lists for the Model 708A are shown in Tables 8-1 through 8-5.

8.3 Ordering information

To place an order or to obtain information concerning replacement parts, contact your Keithley representative or the factory (see inside front cover for addresses). When ordering parts, be sure to include the following information:

- Instrument model number (Model 708A)
- Instrument serial number
- Part description
- Component designation (if applicable)
- Keithley part number

To facilitate repairs, complete circuit boards are available. Contact the Repair Department for pricing and availability.

8.4 Factory service

If the instrument is to be returned to Keithley Instruments for repair, perform the following:

1. Call the Repair Department at 1-800-552-1115 for a Return Material Authorization (RMA) number.
2. Complete the service form at the back of this manual, and include it with the instrument.
3. Carefully pack the instrument in the original packing carton.
4. Write ATTENTION REPAIR DEPARTMENT and the RMA number on the shipping label.

8.5 Component layouts and schematics

The component layouts are provided in the following pages:

Mother board: 708A-100
Display board: 708-110
Backplane board: 708A-120
Front panel control board: 708A-130

A schematic of the Backplane board (708A-126) is also included.

Table 8-1
Model 708A mother board, parts list

Circuit designation	Description	Keithley part no.
	40-PIN SOCKET FOR U103,104,108	SO-84-40
	BATTERY HOLDER FOR BT101	BH-34
	CONNECTOR	CS-276
	CONNECTOR, FEMALE, 4 PIN, SHAPELESS	CS-716-4
	CONNECTOR, JUMPER FOR W101	CS-476
	SOCKET, I.C. 28 PIN FOR U105	SO-69
	SOCKET FOR U116,117	SO-84-20
BT101	BATTERY, LITHIUM-MANGANESE CELL 3V	BA-44
C101,103,123,128-130	CAP,.1UF,20%,50V,CERAMIC	C-365-.1
C102,104	CAP,220UF,-20+100%,25V,ALUM ELEC	C-314-220
C105-109,112-114,116-122,124	CAP,.01UF,20%,50V,CERAMIC	C-365-.01
C110,111	CAP,15PF,10%,1000V,CERAMIC	C-64-15P
C115	CAP, 3.3UF, 10%, 16V, ALUM ELEC	C-321-3.3
CR101-126,129,130,132-137	DIODE,SILICON,IN4148 (DO-35)	RF-28
CR127,128,131,138	DIODE,BRIDGE,VM18	RF-52
J1005,1006	CONN, BNC	CS-547
J1007,1008	CONN, MICRODIN W/GND FINGERS	CS-792
J1009,1010	CONN, FEMALE 25 PIN	CS-628
J1011	CONN,RIGHT ANGLE,24PIN	CS-507
J1015A	CONN, MALE RT ANGLE, 32-PIN CABLE	CS-885-1
J1018,1019	CABLE ASSEMBLY, 16-PIN RIBBON CABLE	CA-27-14C
K101	RELAY, MINIATURE (DPDT)	RL-98
L101,102	CHOKE, 10UH	CH-20-3
R101-108,119-136,138-162,164	RES,10K,5%,1/4W, COMPOSITION OR FILM	R-76-10K
R109-114,118,177-179	RES,3.3K,5%,1/4W, COMPOSITION OR FILM	R-76-3.3K
R115	RES,20K,1%,1/8W, METAL FILM	R-88-20K
R116	RES, 63.4K, 1%, 1/8W, METAL FILM	R-88-63.4K
R117	RES,1M,5%,1/4W, COMPOSITION OR FILM	R-76-1M
R137	RES NET, 47, 5%, 1W	TF-64
R163,165,168-170,175	RES,4.7K,5%,1/4W,COMPOSITION OR FILM	R-76-4.7K
R171	RES NET, 100, 2%, .25W	TF-102-3
R173	RES,10K,5%,1/4W,COMPOSITION OR FILM	R-76-10K
R174,176	RES,100,5%,1/4W,COMPOSITION OR FILM	R-76-100
RT101	POLYSWITCH, PTC RESISTOR	RT-17

Table 8-1 (cont.)
Model 708A mother board, parts list

Circuit designation	Description	Keithley part no.
S101,102	SWITCH	SW-497A
U101	IC,+5V VOLTAGE REGULATOR,LM2940CT	IC-576
U102	IC,8 BIT PAR OUT SHIFT REG,74HCT164	IC-456
U103	IC, VERSATILE INTERFACE ADAPTER, 6522A	LSI-45
U104	IC,8 BIT MICROPROCESSING UNIT,MC68B09	LSI-65
U105	PROGRAM	708A-800-*
U106	IC,32KX8 STATIC CMOS RAM,D43256C-15L	LSI-76
U107	LARGE SCALE IC	LSI-72
U108	IC, PERIPHERAL INTERFACE ADAPTER, 63B21	LSI-61
U109	IC,GPIB ADAPTER,9914A	LSI-49
U110	IC,OCTAL INTERFACE BUS,75160	IC-298
U111	IC, MICROPOWER BIPOLAR MONOLITHIC, 6728	IC-177
U112	IC,OCTAL INTERFACE BUS TRANSCEIVER,75161	IC-299
U113,130	IC,DUAL D FLIP FLOP W/SET & RESE,74HCT74	IC-515
U114	IC,NONVOLATILE CONTROLLER DS1210	IC-541
U115,120,121,124	IC, 4-CHANNEL PWR DRIVER, 2549B	IC-1044
U116	INTEGRATED CIRCUIT	IC-574
U117	INTEGRATED CIRCUIT	IC-573
U118,119	IC OCTAL,EDGE TRIG FLIP FLOP 75HCT374	IC-397
U122,125	IC, QUAD 2 INPUT OR, 74HCT32	IC-443
U123	IC, HEX INVERTER, 74HCT04	IC-444
U126	IC, BUF/LINE DRIVER 74HCT125	IC-552
U127	IC, QUAD 2 INPUT NAND, 74HCT00	IC-399
U128	IC,QUAD 2 INPUT AND GATE,74HCT08	IC-550
U129,131	IC,8-BIT PARALLEL TO SERIAL,74HCT165	IC-548
U132,133	INTEGRATED CIRCUIT	IC-549
U134	IC, QUAD 2 INPUT POSITIVE NAND, 7438	IC-154
U135	IC, QUAD 2-INPUT MULTIPLEXER 74HCT157	IC-553
U136,137	IC, OTC BFR/LINE DRIVER/REC,74HCT244	IC-483
VR101,102	DIODE, ZENER 5.1V,IN751(DO-7)	DZ-59
W101	CONN,3 PIN	CS-339-3
Y101	CRYSTAL, 7.15909MHZ	CR-24-4

*Order present firmware level.

Table 8-2
Model 708A front panel control board, parts list

Circuit designation	Description	Keithley part no.
	CONN, FEMALE, 3 PIN, SHAPELESS	CS-287-3
	CONNECTOR	CS-276
	POWER BUTTON FOR S205	7002-323-1A
C201,203	CAP,.1UF,20%,50V,CERAMIC	C-365-.1
C202,204-211	CAP,.01UF,20%,50V,CERAMIC	C-365-.01
CR201-203	DIODE,SILICON,IN4148 (DO-35)	RF-28
CR204	DIODE,BRIDGE,VM18	RF-52
J1002	CONN, MOLEX, 3-PIN	CS-772-3
J1015B	CONN, MALE RT ANGLE, 32-PIN	CS-885-1
J1017	CONNECTOR, RIGHT ANGLE	CS-362-8
J1020	CONN, RT. ANGLE, MALE MOLEX .156	CS-715-4
P1016	CABLE ASSEMBLY, 26 CONDUCTOR	CA-27-6
P1018,1019	CONN, DUAL 8-PIN-BERG	CS-672-8
R201	RES NET, 10K,5%, .11W	TF-102-2
R202,204	RES,4.7K,5%,1/4W,COMPOSITION OR FILM	R-76-4.7K
R203,205	RES,100,5%,1/4W,COMPOSITION OR FILM	R-76-100
S205	SWITCH,PUSHBUTTON (6 POLE)	SW-466
U201	RES NET,82,5%,.25W	TF-141
U202	RES NET, 150, 2%, .25W	TF-165-1
U203,204	IC,8-BIT SERIAL-INPUT,UNC5895A	IC-537
U205,206	IC, 8-CHANNEL DRIVER, 2597A	IC-538
U207	IC, 4-16 LINE DECODER/MULTI 74HCT154	IC-551
U208	IC,8 BIT PAR OUT SHIFT REG,74HCT164	IC-456
U209	IC,8-BIT PARALLEL TO SERIAL,74HCT165	IC-548
U210	IC, OTC BFR/LINE DRIVER/REC,74HCT244	IC-483
U211	IC, HEX INVERTER, 74HCT04	IC-444

Table 8-3
Model 708A backplane board, parts list

Circuit designation	Description	Keithley part no.
P101	CONNECTOR	CS-882-86
P107	CONNECTOR, CARD EDGE	CS-591-2
P113	CONNECTOR	CS-883-30
P1015	CONN, FEMALE TYPE B HALF SERIES	CS-794-3

Table 8-4
Model 708A display board, parts list

Circuit designation	Description	Keithley part no.
J1016	CONNECTOR, 26 PIN	CS-889-1
DS400-DS500	PILOT LIG, HSMH-T400, LED	PL-92-1

Table 8-5
Model 708A miscellaneous, parts list

Description	Keithley part no.
BOTTOM COVER	708A-305A
CABLE CLAMP	CC-50-1
CARD GUIDE	CG-5-1
CONN, AC RECEPTACLE (LINE FILTER)	LF-6-1
CONN, MOLEX HEADER	CS-716-3
CONNECTOR	CS-276
CONNECTOR, 4-PIN MALE	CS-458
CONNECTOR, FEMALE, 4 PIN, SHAPELESS	CS-716-4
CONNECTOR, HARDWARE KIT FOR IEEE CS	CS-713
FOOT	428-319A
FOOT, BLACK MOLDED POLY FOR POWER SUPPLY	FE-10
FOOT, RUBBER	FE-6
FRONT PANEL	708A-301B
GUIDE RAIL	708A-310A
HANDLE	HH-31-1
LENS	7002-305-3A
LINE CORD	C0-7
LUG	LU-88
MEMBRANE SWITCH, FRONT PANEL	708A-302A
PANEL BLANK	707-316
PANEL, DRESS	708A-318A
POWER SUPPLY	PS-66
REAR PANEL	708A-303B
REAR PANEL ASSY, BACKPLANE	708A-307A
SAFETY COVER	704-311B
SCREWLOCK, FEMALE FOR DIG INPUT/OUTPUT R.P.	CS-725
SHIELD, DIGITAL	708A-306A
TOP COVER	708A-304A

708A-100
ON

LTR.	ECA NO.	REVISION	ENG.	DATE
A	21761	RELEASED		7-9-98

SC 71-9 18GA WIRE

SC-71-4, 18GA WIRE

708A-102

CC-38-2, TIE WRAP
(2 PLACES)

PART OF P1021

* NOTE: FOR FURTHER COMPONENT INFORMATION,
REFER TO 708A PRODUCT STRUCTURE.

MODEL	NEXT ASSEMBLY	QTY
USED ON		

KEITHLEY
KEITHLEY INSTRUMENTS INC.
CLEVELAND, OHIO 44139

DIM ARE IN IN UNLESS OTHERWISE NOTED	DATE 5/15/98	SCALE 1:1	TITLE COMPONENT LAYOUT, MOTHER BOARD
DIM. TOL. UNLESS OTHERWISE SPECIFIED	DRN AJS	APPR. J.S. RS	
XX=±.01 ANG.=±1 XXX=±.005 FRAC.=±1/64	DO NOT SCALE THIS DRAWING	C	NO. 708A-100

PG 1 OF 1

LTR.	ECA NO.	REVISION	ENC.	DATE
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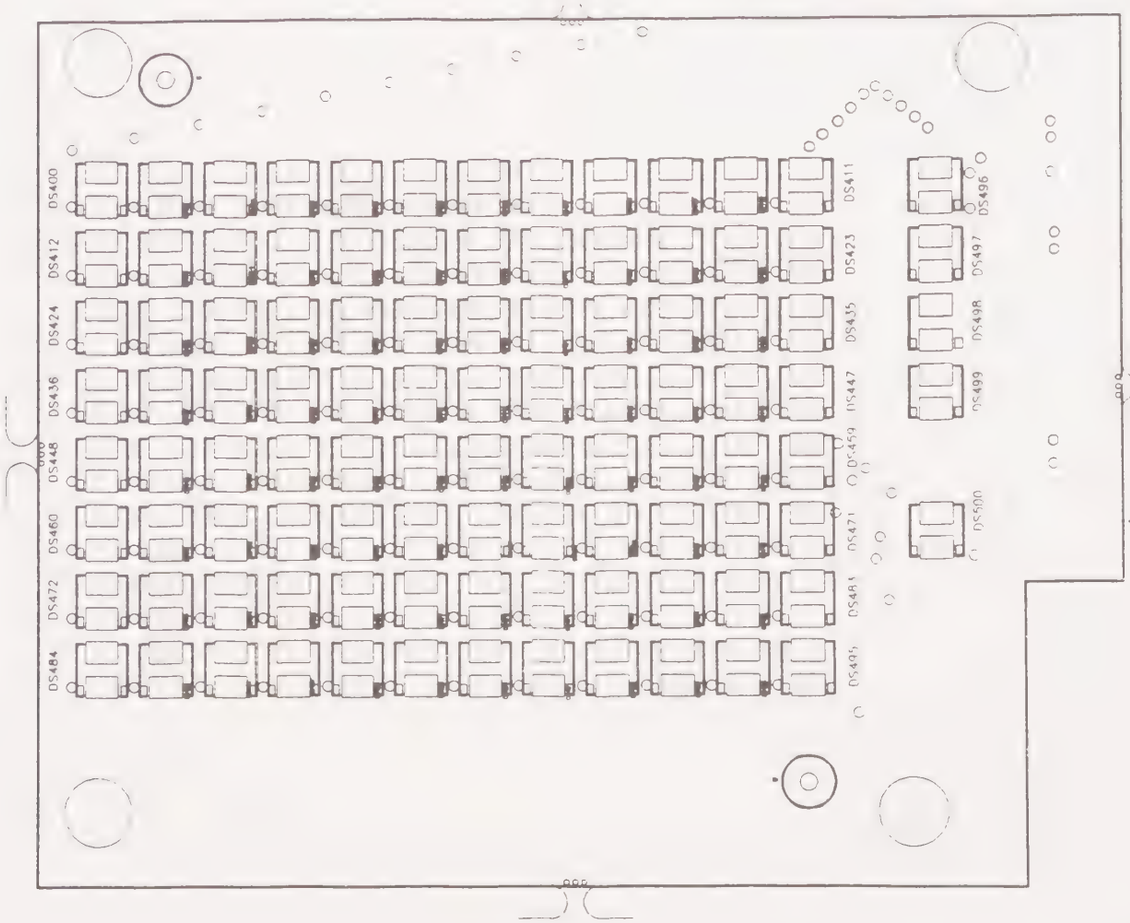


MOUNT SMT CONNECTOR ON SOLDER SIDE

TOP SIDE COMPONENTS (top view)
NOTE: FOR COMPONENT INFORMATION, SEE PRODUCT STRUCTURE.

MODEL	NEXT ASSEMBLY	QTY.
USED ON		

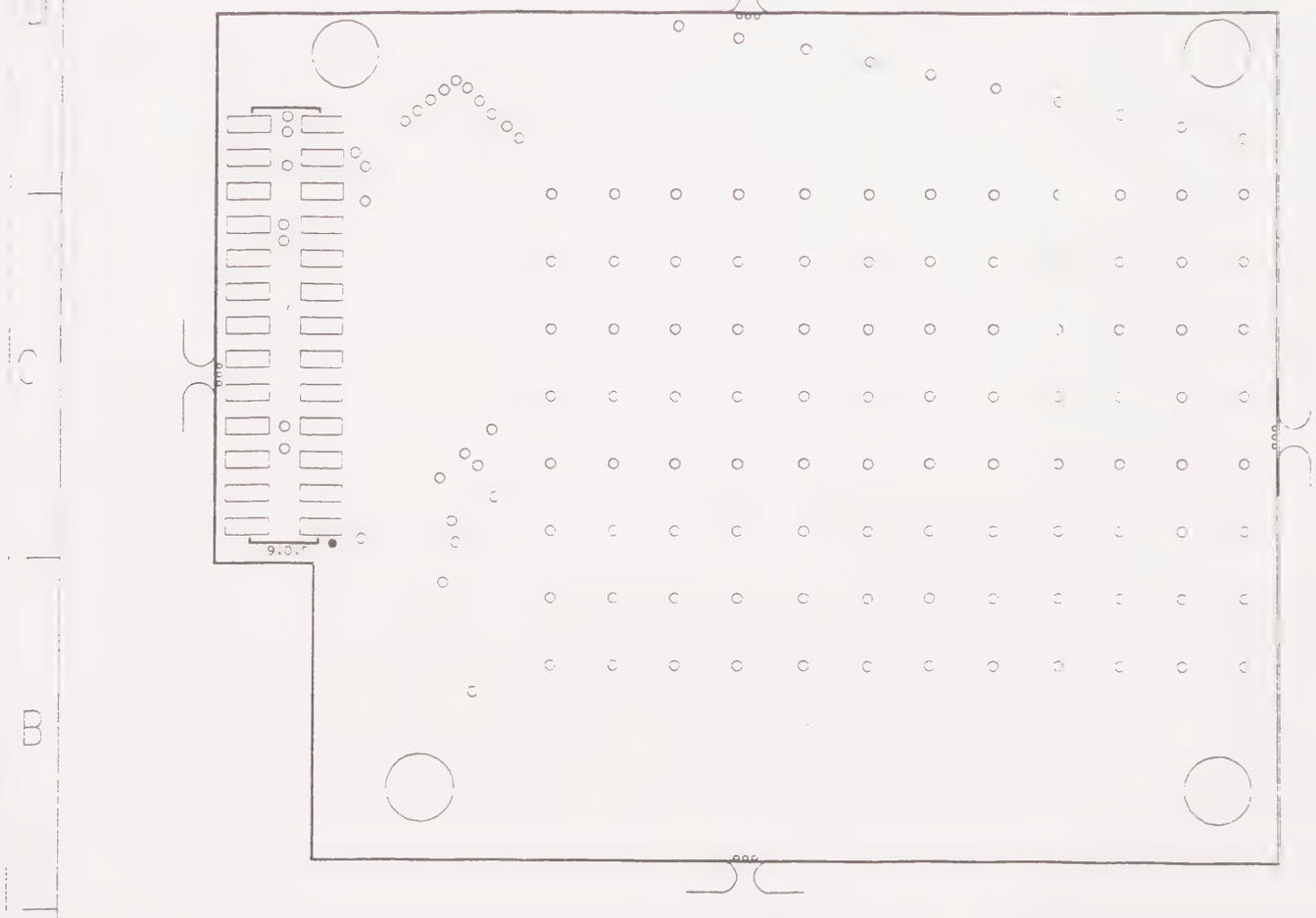
KEITHLEY
KEITHLEY INSTRUMENTS INC.
CLEVELAND, OHIO 44139

DIM ARE IN IN. UNLESS OTHERWISE NOTED
DIM. TOL. UNLESS OTHERWISE SPECIFIED
XX=±.01 ANG.=±1
XXX=±.005 FRAC.=±1/64

DATE 8/23/95 SCALE 2:1
DRN MRS APPR.
DO NOT SCALE THIS DRAWING

TITLE COMPONENT LAYOUT, DISPLAY BOARD
A NO. 708-110

LTR.	ECA NO.	REVISION	ENG.	DATE
B	17864	RELEASED		10-18-95



BOTTOM SIDE COMPONENTS (bottom view)

NOTE: FOR COMPONENT INFORMATION, SEE PRODUCT STRUCTURE.

MODEL	NEXT ASSEMBLY	QTY.
USED ON		

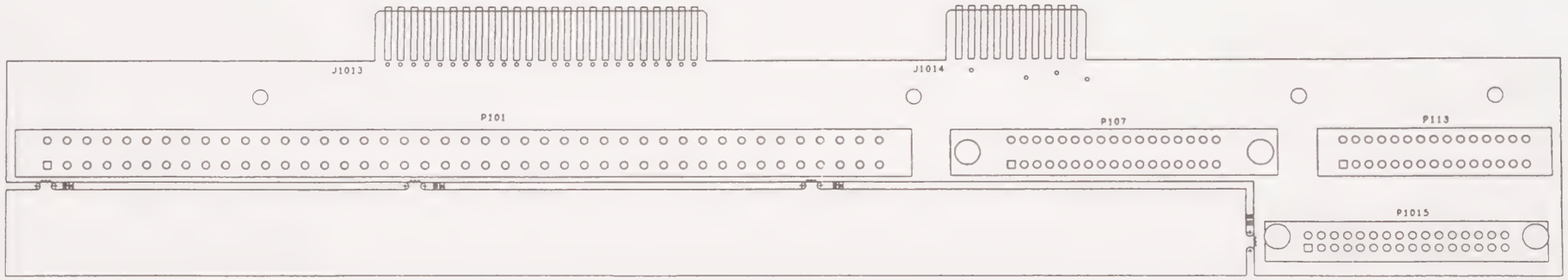
KEITHLEY

KEITHLEY INSTRUMENTS INC.
CLEVELAND, OHIO 44139

DIM ARE IN IN. UNLESS OTHERWISE NOTED	DATE 8/23/95	SCALE 2:1	TITLE COMPONENT LAYOUT, DISPLAY BOARD
DIM. TOL. UNLESS OTHERWISE SPECIFIED	DRN MRS	APPR. J.K	
XX=+.01 ANG.=+1 XXX=+.005 FRAC.=+1/64	DO NOT SCALE THIS DRAWING	A	NO. 708-110

NO.	708A-120

LTR.	ECA NO.	REVISION	ENG.	DATE
A	21761	RELEASED		7-9-98



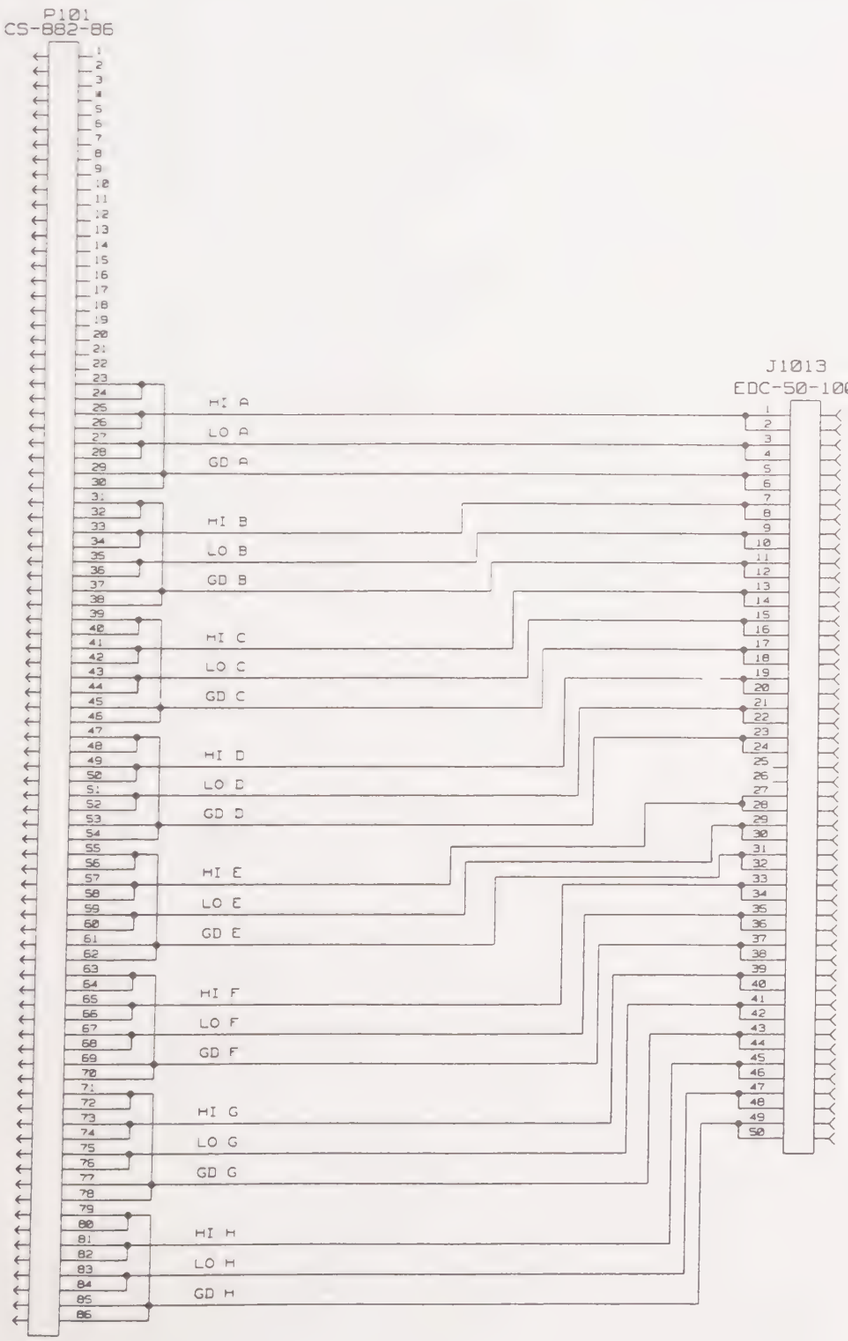
NOTE: FOR COMPONENT INFORMATION, SEE PRODUCT STRUCTURE.

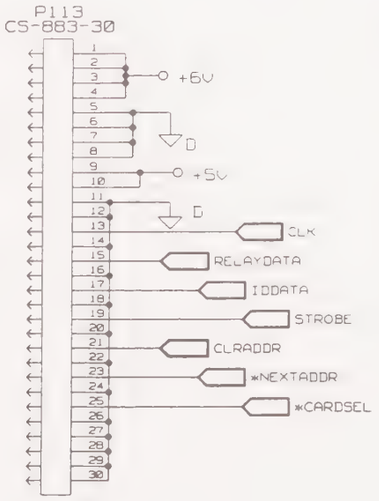
MODEL	NEXT ASSEMBLY	QTY.
USED ON		

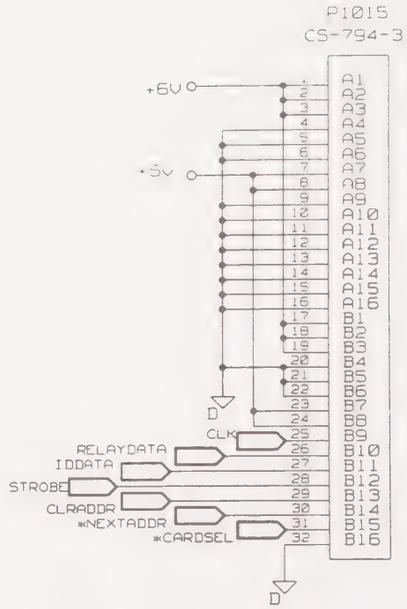
KEITHLEY

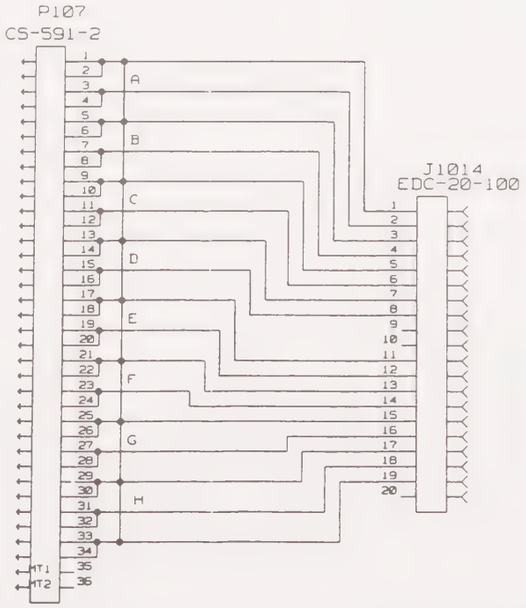
KEITHLEY INSTRUMENTS INC.
CLEVELAND, OHIO 44139

DIM ARE IN IN. UNLESS OTHERWISE NOTED	DATE 5/11/98	SCALE 1:1	TITLE COMPONENT LAYOUT, BACKPLANE BOARD
DIM TOL. UNLESS OTHERWISE SPECIFIED	DRN CAB	APPR. R.S. J.B.	
XX=±.01 ANG.=±1 XXX=±.005 FRAC.=±1/64	DO NOT SCALE THIS DRAWING	B	NO. 708A-120





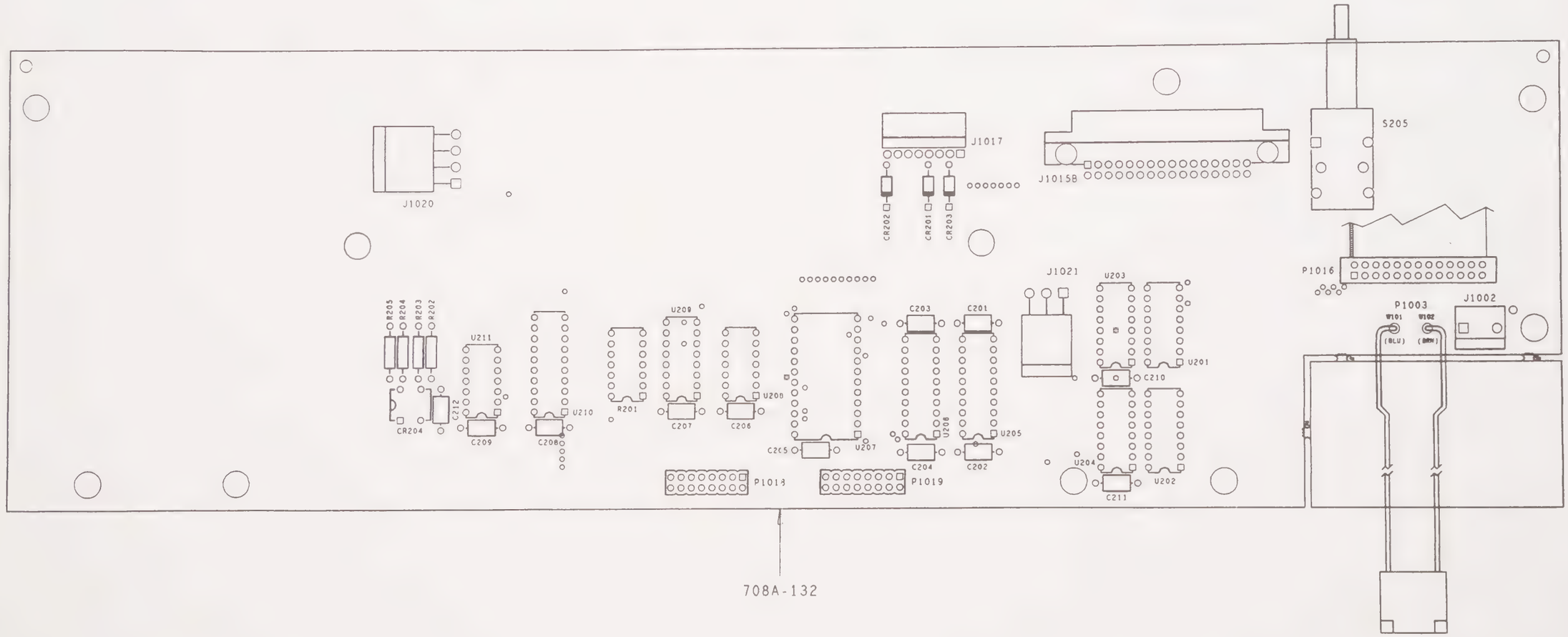




708A_126.LOGIC.1.1

KEITHLEY	KEITHLEY INSTRUMENTS INC. CLEVELAND, OHIO 44139		
DRAWING	BACKPLANE BOARD		BACK
MODEL 708A	B	708A-126	
DRAWN LK	APP J.P.	ECA 21761	REV A
LAST_MODIFIED=Tue Jul 7 13:02:30 1998			

LTR.	ECA NO.	REVISION	ENG.	DATE
A	21761	RELEASED		7-9-98



708A-132

* NOTE: FOR FURTHER COMPONENT INFORMATION, REFER TO 708A PRODUCT STRUCTURE.

MODEL	NEXT ASSEMBLY	QTY.
USED ON		

KEITHLEY

KEITHLEY INSTRUMENTS INC.
CLEVELAND, OHIO 44139

DIM ARE IN IN. UNLESS OTHERWISE NOTED	DATE 5/15/98	SCALE 1:1	TITLE COMPONENT LAYOUT, FRONT PANEL CONTROL BD.
DIM. TOL. UNLESS OTHERWISE SPECIFIED	DRN AJS	APPR. P.S.P.	
XX=±.01 ANG.=±1 XXX=±.005 FRAC.=±1/64	DO NOT SCALE THIS DRAWING	B	NO. 708A-130

PG 1 OF 1

A

Card Configuration Worksheet

Card model number: _____

Stand-alone _____

Master _____ Slave 1 _____ Slave 2 _____ Slave 3 _____ Slave 4 _____

System size:
Total crosspoints _____ rows _____ columns _____ IEEE address _____

FROM (Instrument connection or DUT pin)	**External Card Connection**	**TO** (Instrument connection or DUT pin)
	Row A	
	B	
	C	
	D	
	E	
	F	
	G	
	H	
	Column 1	
	2	
	3	
	4	
	5	
	6	
	7	
	8	
	9	
	10	
	11	
	12	

Expansion:

___ Backplane bus (rows through ribbon cable)
___ Point to point writing (rows/cols.)
___ Triax cable (rows/cols.)
___ Mass terminated cable (rows/cols.)
___ BNC coax cable (rows/cols.)
___ Partial matrix expansion

Notes:

B

I/O Connections

B.1 Typical output connection schemes

The following examples show output connections from the I/O circuitry to external circuitry and summarize the required internal connections on the card.

Solenoid control — Figure B-1 shows a digital connection scheme to control solenoids. This example assumes that an external 24V source is being used. The pull-up resistors for output channels 1, 2, and 3 are removed for this application.

A solenoid is energized when the corresponding output channel is turned on (closed).

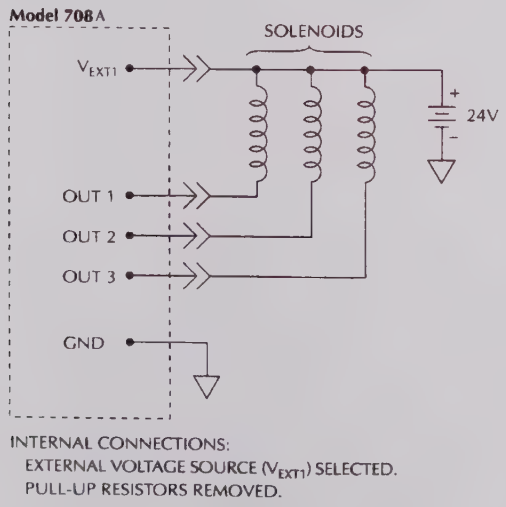


Figure B-1
Digital output, solenoid control

Relay control — Figure B-2 shows a digital output connection scheme to control relays. This example assumes that the internal 5.3V source is being used, and the pull-up resistors for output channels 9, 10, and 11 are removed.

A relay coil is energized when the corresponding output channel is turned on (closed).

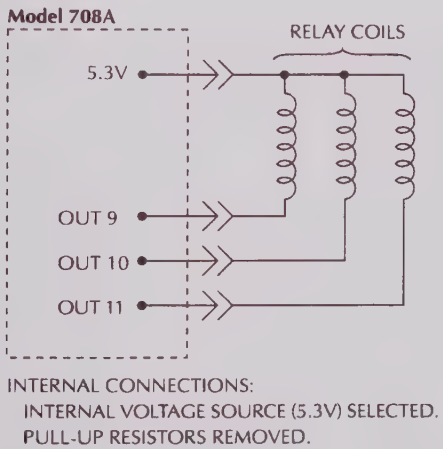


Figure B-2
Digital output, relay control

Motor control — Figure B-3 shows a digital output connection scheme to control small 12VDC motors. An external 12V source is used to provide the necessary voltage level. This example assumes that the pull-up resistors for channels 14 and 15 are removed.

A motor is turned on when the corresponding output channel is turned on (closed).

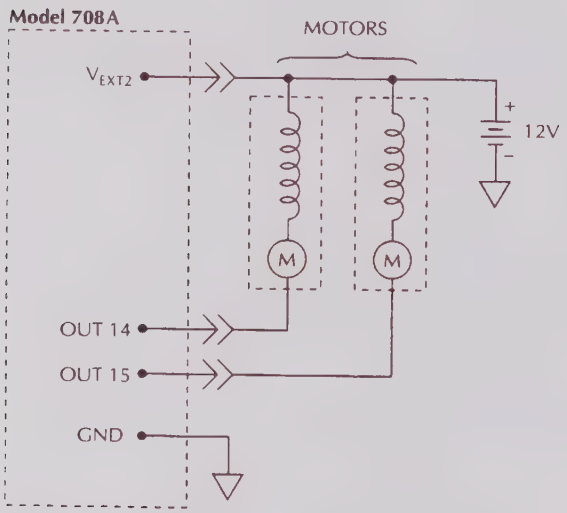


Figure B-3
Digital output, motor control

Logic device control — Figure B-4 shows a digital output connection scheme to control a logic device. This example assumes that the internal 5V source is being used, and the pull-up resistors for channels 14, 15, and 16 are installed.

The logic device is a demultiplexer (DMUX). The binary pattern (value) seen at the input of the DMUX (lines A, B, and C) determines which DMUX output line (Y0 through Y7) is selected (pulled low). For example, with channels 14, 15, and 16 off (open), lines A, B, and C are high. The binary 7 at the DMUX input (A=1, B=1, and C=1) selects (pulls low) output Y7. If channel 15 is turned on (closed), line B goes low. The binary 5 seen at the DMUX input (1, 0, 1) selects (pulls low) Y5.

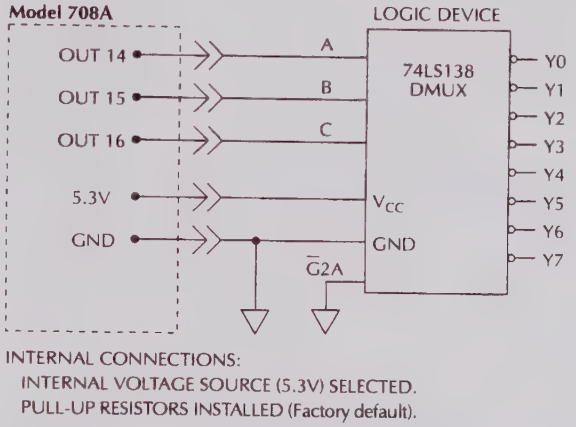


Figure B-4
Digital output, logic device control

B.2 Typical input connection scheme

Figure B-5 shows a digital input connection scheme to monitor the state of micro-switches. With a switch open, the corresponding input channel is pulled high by the internal pull-up resistor. As a result, the input channel is on (closed).

When a switch is closed, the corresponding input channel is pulled low to ground. As a result, the input channel is off (open).

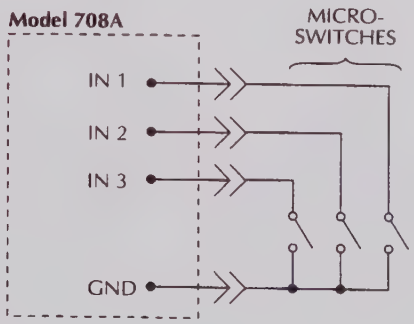


Figure B-5
Digital input, monitoring micro-switches

C

IEEE-488 Bus Overview

C.1 Introduction

The IEEE-488 bus is a communication system between two or more electronic devices. A device can be either an instrument or a computer. When a computer is used on the bus, it serves as a supervisor of the communication exchange between all the devices and is known as the controller. Supervision by the controller consists of determining which device will talk and which device will listen. As a talker, a device will output information. As a listener, a device will receive information. To simplify the task of keeping track of the devices, a unique address number is assigned to each.

On the bus, only one device can talk at a time and is addressed to talk by the controller. The device that is talking is known as the active talker. The devices that need to listen to the talker are addressed to listen by the controller. Each listener is then referred to as an active listener. Devices that do not need to listen are instructed to unlisten. The reason for the unlisten instruction is to optimize the speed of bus information transfer since the task of listening takes up bus time.

Through the use of control lines, a handshake sequence takes place in the transfer process of information from a talker to a listener. This handshake sequence helps ensure the credibility of the information transfer. The basic handshake sequence between an active controller (talker) and a listener is:

1. The listener indicates that it is ready to listen.
2. The talker places the byte of data on the bus and indicates that the data is available to the listener.
3. The listener, aware that the data is available, accepts the data and then indicates that the data has been accepted.
4. The talker, aware that the data has been accepted, stops sending data and indicates that data is not being sent.
5. The listener, aware that there is no data on the bus, indicates that it is ready for the next byte of data.

C.2 Bus description

The IEEE-488 bus, which is also referred to as the GPIB (General Purpose Interface Bus), was designed as a parallel transfer medium to optimize data transfer without using an excessive number of bus lines. In keeping with this goal, the bus has only eight data lines that are used for data and with most commands. Five bus management lines and three handshake lines round out the complement of bus signal lines

A typical setup for controlled operation is shown in Figure C-1. Generally, a system will contain one controller and a number of other instruments to which the commands are given. Device operation is categorized into three operators: controller, talker, and listener. The controller controls the instruments on the bus. The talker sends data while a listener receives data. Depending on the type of instrument, any particular device can be a talker only, a listener only, or both a talker and listener.

There are two categories of controllers: system controller and basic controller. Both are able to control other instruments, but only the system controller has the absolute authority in the system. In a system with more than one controller, only one controller may be active at any given time. Certain protocol is used to pass control from one controller to another.

The IEEE-488 bus is limited to 15 devices, including the controller. Thus, any number of talkers and listeners up to that limit may be present on the bus at one time. Although several devices may be commanded to listen simultaneously, the bus can have only one active talker, or communications would be scrambled.

A device is placed in the talk or listen state by sending an appropriate talk or listen command. These talk and listen commands are derived from an instrument's primary address. The primary address may have any value between 0 and 31, and is generally set by rear panel DIP switches or programmed in from the front panel of the instrument. The actual listen address value sent out over the bus is obtained by ORing the primary address with $20. For example, if the primary address is $16, the actual listen address is $36 ($36 = $16 + $20). In a similar manner, the talk address is obtained by ORing the primary address with $40. With the present example, the talk address derived from a primary address of $16 would be $56 ($56 = $16 + $40).

The IEEE-488 standards also include another addressing mode called secondary addressing. Secondary addresses lie in the range of $60-$7F. Note, however, that many devices, including the Model 708A, do not use secondary addressing.

Once a device is addressed to talk or listen, the appropriate bus transactions take place. For example, if the instrument is addressed to talk, it places its data string on the bus one byte at a time. The controller reads the information, and the appropriate software can be used to direct the information to the desired location.

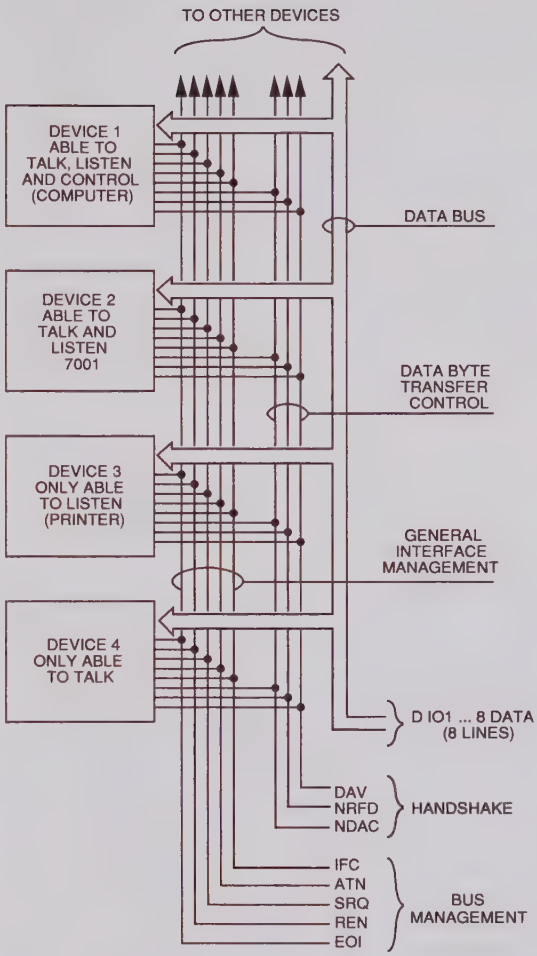


Figure C-1
IEEE-488 bus configuration

C.3 Bus lines

The signal lines on the IEEE-488 bus are grouped into three different categories: data lines, management lines, and handshake lines. The data lines handle bus data and commands, while the management and handshake lines ensure that proper data transfer and operation take place. Each bus line is active low, with approximately zero volts representing a logic 1 (true). The following paragraphs describe the operation of these lines.

C.3.1 Data lines

The IEEE-488 bus uses eight data lines that transfer data one byte at a time. DIO1 (Data Input/Output) through DIO8 (Data Input/Output) are the eight bi-directional data lines used to transmit both data and multiline commands. The data lines operate with low true logic.

C.3.2 Bus management lines

The five bus management lines help to ensure proper interface control and management. These lines are used to send the uniline commands.

- ATN (Attention) — The state of the ATN line determines how information on the data bus is to be interpreted.
- IFC (Interface Clear) — The IFC line controls clearing of instruments from the bus.
- REN (Remote Enable) —The REN line is used to place the instrument on the bus in the remote mode.
- EOI (End or Identify) — The EOI line is used to mark the end of a multi-byte data transfer sequence.
- SRQ (Service Request) — The SRQ line is used by devices when they require service from the controller.

C.3.3 Handshake lines

The bus handshake lines operate in an interlocked sequence. This method ensures reliable data transmission regardless of the transfer rate. Generally, data transfer will occur at a rate determined by the slowest active device on the bus.

One of the three handshake lines is controlled by the source (the talker sending information), while the remaining two lines are controlled by accepting devices (the listener(s) receiving the information). The three handshake lines are:

- DAV (DATA VALID) — The source controls the state of the DAV line to indicate to any listening devices whether or not data bus information is valid.
- NRFD (Not Ready For Data) — The acceptor controls the state of NRFD. It is used to signal to the transmitting device to hold off the byte transfer sequence until the accepting device is ready.
- NDAC (Not Data Accepted) — NDAC is also controlled by the accepting device. The state of NDAC tells the source whether or not the device has accepted the data byte.

The complete handshake sequence for one data byte is shown in Figure C-2. Once data is placed on the data lines, the source checks to see that NRFD is high, indicating that all active devices are ready. At the same time, NDAC should be low from the previous byte transfer. If these conditions are not met, the source must wait until NDAC and NRFD have the correct status. If the source is a controller, NRFD and NDAC must be stable for at least 100ns after ATN is set true. Because of the possibility of a bus hang up, many controllers have time-out routines that display messages in case the transfer sequence stops for any reason.

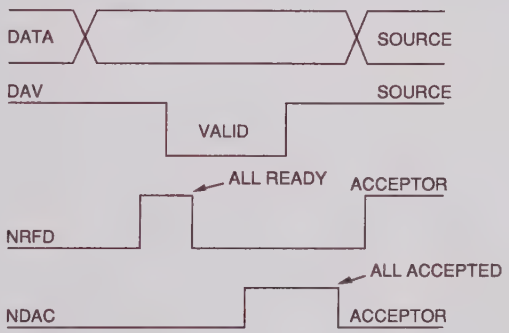


Figure C-2
IEEE-488 handshake sequence

Once all NDAC and NRFD are properly set, the source sets DAV low, indicating to accepting devices that the byte on the data lines is now valid. NRFD will then go low, and NDAC will go high once all devices have accepted the data. Each device will release NDAC at its own rate, but NDAC will not be released to go high until all devices have accepted the data byte.

The previous sequence is used to transfer both data, talk, and listen addresses, as well as multiline commands. The state of the ATN line determines whether the data bus contains data, addresses, or commands as described in the following paragraphs.

C.4 Bus commands

The instrument may be given a number of special bus commands through the IEEE-488 interface. The following paragraphs briefly describe the purpose of the bus commands that are grouped into the following categories.

- Uniline commands — Sent by setting the associated bus lines true. For example, to assert REN (Remote Enable), the REN line would be set low (true).
- Multiline commands — General bus commands that are sent over the data lines with the ATN line true (low).
- Common commands — Commands that are common to all devices on the bus and are sent with ATN high (false).
- SCPI commands — Commands that are particular to each device on the bus and are sent with ATN (false).

These bus commands and their general purpose are summarized in Table C-1.

C.4.1 Uniline commands

ATN, IFC, and REN are asserted only by the controller. SRQ is asserted by an external device. EOI may be asserted either by the controller or other devices depending on the direction of data transfer. The following is a description of each command. Each command is sent by setting the corresponding bus line true.

- REN (Remote Enable) — REN is sent to set up instruments on the bus for remote operation. When REN is true, devices will be removed from the local mode. Depending on device configuration, all front panel controls except the LOCAL button (if the device is so equipped) may be locked out when REN is true. Generally, REN should be sent before attempting to program instruments over the bus.
- EOI (End or Identify) — EOI is used to positively identify the last byte in a multi-byte transfer sequence, thus allowing data words of various lengths to be transmitted easily.
- IFC (Interface Clear) — IFC is used to clear the interface and return all devices to the talker and listener idle states.
- ATN (Attention) — The controller sends ATN while transmitting addresses or multiline commands.
- SRQ (Service Request) — SRQ is asserted by a device when it requires service from a controller.

Table C-1
IEEE-488 bus command summary

Command type	Command	State of ATN line	Comments
Uniline	REN (Remote Enable)	X	Set up devices for remote operation.
	EOI	X	Marks end of transmission.
	IFC (Interface Clear)	X	Clears interface.
	ATN (Attention)	Low	Defines data bus contents.
	SRQ	X	Controlled by external device.
Multiline Universal	LLO (Local Lockout)	Low	Locks out local operation.
	DCL (Device Clear)	Low	Returns device to default conditions.
	SPE (Serial Enable)	Low	Enables serial polling.
	SPD (Serial Poll Disable)	Low	Disables serial polling.
Addressed	SDC (Selective Device Clear)	Low	Returns unit to default conditions.
	GTL (Go To Local)	Low	Returns device to local.
Unaddressed	UNL (Unlisten)	Low	Removes all listeners from the bus.
	UNT (Untalk)	Low	Removes any talkers from the bus.

C.4.2 Universal multiline commands

Universal commands are those multiline commands that require no addressing. All devices equipped to implement such commands will do so simultaneously when the commands are transmitted. As with all multiline commands, these commands are transmitted with ATN true.

- LLO (Local Lockout) — LLO is sent to the instrument to lock out the LOCAL key and all their front panel controls.
- DCL (Device Clear) — DCL is used to return instruments to some default state. Instruments usually return to their power-up conditions.
- SPE (Serial Poll Enable) — SPE is the first step in the serial polling sequence that is used to determine which device has requested service.
- SPD (Serial Poll Disable) — SPD is used by the controller to remove all devices on the bus from the serial poll mode and is generally the last command in the serial polling sequence.

C.4.3 Addressed multiline commands

Addressed commands are multiline commands that must be preceded by the device listen address before that instrument will respond to the command in question. Note that only the addressed device will respond to these commands. Both the commands and the address preceding it are sent with ATN true.

- SDC (Selective Device Clear) — The SDC command performs essentially the same function as the DCL command except that only the addressed device responds. Generally, instruments return to their power-up default conditions when responding to the SDC command.
- GTL (Go To Local) — The GTL command is used to remove instruments from the remote mode. With some instruments, GTL also unlocks front panel controls if they were previously locked out with the LLO command.
- GET (Group Execute Trigger) — The GET command is used to trigger devices to perform a specific action that depends on device configuration (for example, take a reading). Although GET is an addressed command, many devices respond to GET without addressing.

C.4.4 Address commands

Addressed commands include two primary command groups and a secondary address group. ATN is true when these commands are asserted. The commands include:

- LAG (Listen Address Group) — These listen commands are derived from an instrument's primary address and are used to address devices to listen. The actual command byte is obtained by ORing the primary address with $20.
- TAG (Talk Address Group) — The talk commands are derived from the primary address by ORing the address with $40. Talk commands are used to address devices to talk.
- SCG (Secondary Command Group) — Commands in this group provide additional addressing capabilities. Many devices (including the Model 708A) do not use these commands.

C.4.5 Unaddress commands

The two unaddress commands are used by the controller to remove any talkers or listeners from the bus. ATN is true when these commands are asserted.

- UNL (Unlisten) — Listeners are placed in the listener idle state by the UNL command.
- UNT (Untalk) — Any previously commanded talkers will be placed in the talker idle state by the UNT command.

C.4.6 Command codes

Command codes for the various commands that use the data lines are summarized in Figure C-3. Hexadecimal and decimal values for the various commands are listed in Table C-2.

Table C-2
Hexadecimal and decimal command codes

Command	Hex value	Decimal value
GTL	01	1
SDC	04	4
GET	08	8
LLO	11	17
DCL	14	20
SPE	18	24
SPD	19	25
LAG	20-3F	32-63
TAG	40-5F	64-95
SCG	60-7F	96-127
UNL	3F	63
UNT	5F	95

D_7 D_6 D_5 D_4						X 0 0 0	Command	X 0 0 1	Command	X 0 1 0	Primary Address	X 0 1 1	Primary Address	X 1 0 0	Primary Address	X 1 0 1	Primary Address	X 1 1 0		X 1 1 1	
Bits	D_3 ↓	D_2 ↓	D_1 ↓	D_0 ↓	Column→ Row ↓	0 (A)	0 (B)	1 (A)	1 (B)	2 (A)	2 (B)	3 (A)	3(B)	4 (A)	4 (B)	5 (A)	5 (B)	6 (A)	6 (B)	7 (A)	7 (B)
	0	0	0	0	0	NUL		DLE		SP	0	0	16	@	0	P	16			p	
	0	0	0	1	1	SOH	GTL	DC1	LLO	!	1	1	17	A	1	Q	17	a		q	
	0	0	1	0	2	STX		DC2		"	2	2	18	B	2	R	18	b		r	
	0	0	1	1	3	ETX		DC3		#	3	3	19	C	3	S	19	c		s	
	0	1	0	0	4	EOT	SDC	DC4	DCL	$	4	4	20	D	4	T	20	d		t	
	0	1	0	1	5	ENQ	PPC*	NAK	PPU*	%	5	5	21	E	5	U	21	e		u	
	0	1	1	0	6	ACK		SYN		&	6	6	22	F	6	V	22	f		v	
	0	1	1	1	7	BEL		ETB		'	7	7	23	G	7	W	23	g		w	
	1	0	0	0	8	BS	GET	CAN	SPE	(	8	8	24	H	8	X	24	h		x	
	1	0	0	1	9	HT	TCT*	EM	SPD	)	9	9	25	I	9	Y	25	i		y	
	1	0	1	0	10	LF		SUB		*	10	:	26	J	10	Z	26	j		z	
	1	0	1	1	11	VT		ESC		+	11	;	27	K	11	[	27	k		{	
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	1	1	0	1	13	CR		GS		-	13	=	29	M	13	]	29	m		}	
	1	1	1	0	14	SO		RS		.	14	>	30	N	14	∩	30	n		~	
	1	1	1	1	15	SI		US		/	15	?	UNL	O	15	—	UNT	o		DEL	

ADDRESSED COMMAND GROUP (ACG)

UNIVERSAL COMMAND GROUP (UCG)

LISTEN ADDRESS GROUP (LAG)

TALK ADDRESS GROUP (TAG)

PRIMARY COMMAND GROUP (PCG)

SECONDARY COMMAND GROUP (SDC)

*PPC (PARALLEL POLL CONFIGURE) PPU (PARALLEL POLL UNCONFIGURE), and TCT (TAKE CONTROL) not implemented by Model 708A.

Note: D_0 = DIO1 ... D_7 = DIO8; X = Don't Care.

Figure C-3
Command codes

C.4.7 Typical command sequences

For the various multiline commands, a specific bus sequence must take place to properly send the command. In particular, the correct listen address must be sent to the instrument before it will respond to addressed commands. Table C-3 lists a typical bus sequence for sending the addressed multiline commands. In this instance, the SDC command is being sent to the instrument. UNL is generally sent as part of the sequence to ensure that no other active listeners are present. Note that ATN is true for both the listen command and the SDC command byte itself.

Table C-3
Typical addressed command sequence

Step	Command	ATN state	Data bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	0	30	48
3	SDC	Stays low	EOT	04	4
4		Returns high			

*Assumes primary address = 16.

Table C-4 gives a typical common command sequence. In this instance, ATN is true while the instrument is being addressed, but it is set high while sending the common command string.

Table C-4
Typical addressed command sequence

Step	Command	ATN state	Data bus		
			ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	0	30	48
3	Data	Set high	*	2A	42
4	Data	Stays high	R	52	82
5	Data	Stays high	S	53	83
6	Data	Stays high	T	54	84

*Assumes primary address = 16.

C.4.8 IEEE command groups

Command groups supported by the Model 708A are listed in Table C-5.

Table C-5
IEEE command groups

HANDSHAKE COMMAND GROUP	
	NDAC = NOT DATA ACCEPTED
	NRFD = NOT READY FOR DATA
	DAV = DATA VALID
UNIVERSAL COMMAND GROUP	
	ATN = ATTENTION
	DCL = DEVICE CLEAR
	IFC = INTERFACE CLEAR
	REN = REMOTE ENABLE
	SPD = SERIAL POLL DISABLE
	SPE = SERIAL POLL ENABLE
ADDRESS COMMAND GROUP	
LISTEN	LAG = LISTEN ADDRESS GROUP
	MLA = MY LISTEN ADDRESS
	UNL = UNLISTEN
TALK	TAG = TALK ADDRESS GROUP
	MTA = MY TALK ADDRESS
	UNT = UNTALK
	OTA = OTHER TALK ADDRESS
ADDRESSED COMMAND GROUP	
	ACG = ADDRESSED COMMAND GROUP
	GTL = GO TO LOCAL
	SDC = SELECTIVE DEVICE CLEAR
STATUS COMMAND GROUP	
	RQS = REQUEST SERVICE
	SRQ = SERIAL POLL REQUEST
	STB = STATUS BYTE
	EOI = END

C.5 Interface function codes

The interface function codes, which are part of the IEEE-488 standards, define an instrument's ability to support various interface functions and should not be confused with programming commands found elsewhere in this manual. The interface function codes for the Model 708A are listed in Table C-6.

Table C-6
Model 708A interface function codes

Code	Interface function
SH1	Source Handshake capability
AH1	Acceptor Handshake capability
T5	Talker (basic talker, talk-only, serial poll, unaddressed to talk on LAG)
L4	Listener (basic listener, unaddressed to listen on TAG)
SR1	Service Request capability
RL1	Remote/Local capability
PP0	No Parallel Poll capability
DC1	Device Clear capability
DT1	Device Trigger capability
C0	No Controller capability
E1	Open collector bus drivers
TE0	No Extended Talker capability
LE0	No Extended Listener capability

The codes define Model 708A capabilities as follows:

- SH (Source Handshake Function) — SH1 defines the ability of the instrument to initiate the transfer of message/data over the data bus.
- AH (Acceptor Handshake Function) — AH1 defines the ability of the instrument to guarantee proper reception of message/data transmitted over the data bus.
- T (Talker Function) — The ability of the instrument to send data over the bus to other devices is provided by the T function. Instrument talker capabilities (T5) exist only after the instrument has been addressed to talk.
- L (Listener Function) — The ability of the instrument to receive device-dependent data over the bus from other devices is provided by the L function. Listener capabilities (L4) of the instrument exist only after it has been addressed to listen.
- SR (Service Request Function) — SR1 defines the ability of the instrument to request service from the controller.
- RL (Remote/Local Function) — RL1 defines the ability of the instrument to be placed in the remote or local modes.
- PP (Parallel Poll Function) — The instrument does not have parallel polling capabilities (PP0).
- DC (Device Clear Function) — DC1 defines the ability of the instrument to be cleared (initialized).
- DT (Device Trigger Function) — DTI defines the ability of the Model 708A to have readings triggered.
- C (Controller Function) — The instrument does not have controller capabilities (C0).
- E (Bus Driver Type) — The instrument has open-collector bus drivers (E1).
- TE (Extended Talker Function) — The instrument does not have extended talker capabilities (TE0).
- LE (Extended Listener Function) — The instrument does not have extended listener capabilities (LE0).

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Service Form

Model No. _____ **Serial No.** _____ **Date** _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

_____

_____

- ❑ Intermittent
- ❑ Analog output follows display
- ❑ Particular range or function bad; specify _____
- ❑ IEEE failure
- ❑ Obvious problem on power-up
- ❑ Batteries and fuses are OK
- ❑ Front panel operational
- ❑ All ranges or functions are bad
- ❑ Checked all cables

Display or output (check one)

- ❑ Drifts
- ❑ Unstable
- ❑ Overload
- ❑ Unable to zero
- ❑ Will not read applied input

- ❑ Calibration only
- ❑ Data required
- ❑ Certificate of calibration required

(attach any additional sheets as necessary)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)

_____

_____

What power line voltage is used? _____ Ambient temperature? _____ °F

Relative humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe.)

_____

_____

Be sure to include your name and phone number on this service form.

KEITHLEY

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Printed in the U.S.A.

Instruction Manual

Model 7174A

8×12 Low Current Matrix Card

Contains Operating and Servicing Information

KEITHLEY

7174A-901-01 Rev. A / 9-98

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment.

Keithley Instruments, Inc. warrants the following items for 90 days from the date of shipment: probes, cables, rechargeable batteries, diskettes, and documentation.

During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the product, transportation prepaid, to the indicated service facility. Repairs will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days.

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This warranty does not apply to defects resulting from product modification without Keithley's express written consent, or misuse of any product or part. This warranty also does not apply to fuses, software, non-rechargeable batteries, damage from battery leakage, or problems arising from normal wear or failure to follow instructions.

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10/99

Model 7174A 8×12 Low Current Matrix Card
Instruction Manual

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Manual Print History

The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

Revision A (Document Number 7174A-901-01)..... September 1998

All Keithley product names are trademarks or registered trademarks of Keithley Instruments, Inc.

Other brand and product names are trademarks or registered trademarks of their respective holders.

Safety Precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read the operating information carefully before using the product.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Users of this product must be protected from electric shock at all times. The responsible body must ensure that users are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product users in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

As described in the International Electrotechnical Commission (IEC) Standard IEC 664, digital multimeter measuring circuits (e.g., Keithley Models 175A, 199, 2000, 2001, 2002, and 2010) are Installation Category II. All other instruments' signal terminals are Installation Category I and must not be connected to mains.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.

When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

7174A 8×12 Low Current Matrix Card Specifications

MATRIX CONFIGURATION: Single 8 rows×12 columns. Expanding the columns can be done internally by connecting the rows of multiple 7174A cards together with coax jumpers.

CROSSPOINT CONFIGURATION: 2-pole Form A (Signal Guard).

CONNECTOR TYPE: 3-lug triax (Signal, Guard, Chassis).

MAXIMUM SIGNAL LEVEL:
Pin to Pin or Pin to Chassis: 200V. 2A carry current.

CONTACT LIFE: Cold Switching: 10^8 closures.

OFFSET CURRENT: 100fA max., 10fA typical (with 0V applied to inputs and outputs).

ISOLATION: Path (Signal to Signal): $>2\times10^{14}\Omega$, 1pF.
Common (Signal to Chassis): $>10^{14}\Omega$, <10pF.

SETTLING TIME: <2.5s to 400fA (all pathways) after 10V applied (typical).

CROSSTALK (1MHz, 50Ω Load): <–70dB.

INSERTION LOSS (1MHz, 50Ω Load): <–0.2dB typical.

3dB BANDWIDTH:
(50Ω Load, 50Ω Source): 30MHz typical.
(1MΩ Load, 50Ω Source): 40MHz typical.

RELAY DRIVE CURRENT (per crosspoint): 17mA.

RELAY SETTLING TIME: <1ms.

ENVIRONMENT:
Offset Current and Path Isolation Specifications: 23°C, <60% R.H.
Operating: 0° to 50°C, up to 35°C at 70% R.H.
Storage: –25° to +65°C.

MAXIMUM LEAKAGE:
Pin to Ground: 0.01pA/V. **Pin to Pin:** 0.005pA/V.

INSULATION RESISTANCE: $6.7\times10^{13}\Omega$ minimum.

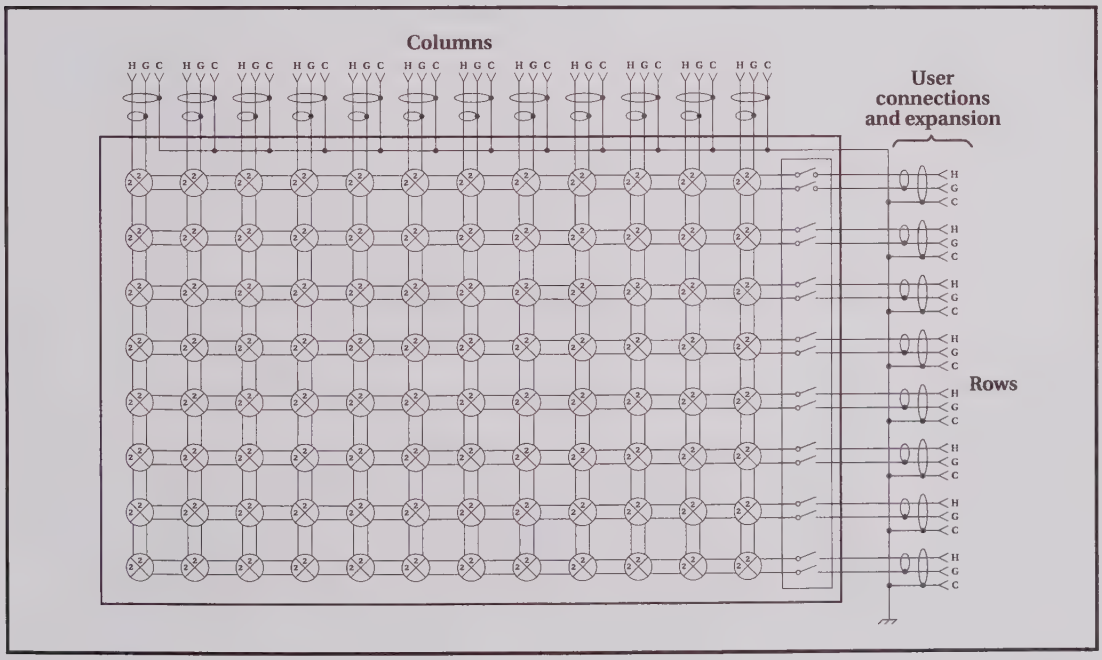
CAPACITANCE: (Guard Driven): Path to Ground: <10pF. **Path to Path:** 1pF typical.

ACCESSORY SUPPLIED: Instruction manual and eight MCX expansion cables.

ACCESSORIES AVAILABLE:

7078-TRX-TBC	3-Lug Triax to BNC Adapter
7078-TRX-T	3-Lug Triax Tee Adapter
7078-TRX-3	3-Lug Triax Cable, 0.9m (3 ft.)
7078-TRX-10	3-Lug Triax Cable, 3m (10 ft.)
7078-TBC	3-Lug Female Triax Bulkhead Connector with Cap
7078-CSHP	Cable Set to Connect 7174 to HP 4145, 4155, 4156

Specifications are subject to change without notice.



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1 General Information

1.1 Introduction

This section contains general information about the Model 7174A Low Current Matrix Card. The Model 7174A Low Current Matrix Card is designed for semiconductor research, development, and production applications that require high quality and performance switching I-V (current versus voltage) and C-V (capacitance versus voltage) signals. The model 7174A is ideal for use with Keithley Model 236 Source Measure Unit for semiconductor testing and other low current switching applications. Model 237 and Model 238 Source Measure Units can also be used below the maximum signal level (200V, 2A carry) of the Model 7174A Low Current Matrix Card (for full specifications, refer to paragraph 1.6). The Model 7174A also can be used with Models 590 and 595 C-V instruments.

Section 1 is arranged in the following manner:

1.2 Features

1.3 Warranty information

1.4 Manual addenda

1.5 Safety symbols and terms

1.6 Specifications

1.7 Unpacking and inspection

1.8 Packing for shipment

1.9 Optional accessories

1.2 Features

Key features of the Model 7174A Low Current Matrix Card include:

- Eight row by twelve column (8×12) switching matrix configuration, with signal and guard switched at each crosspoint
- Paths have offset currents of less than 100fA with typical offset currents of 50fA
- Maximum Leakage Currents:

  Pin to Ground -- 0.01 pA/V

  Pin to Pin -- 0.005 pA/V
- 3-lug Triaxial Connectors (Signal, Guard, Chassis) for all row and columns allow guarding of each signal pathway, minimizing effects of stray capacitance, leakage current, and leakage resistance
- Model 7174A cards can be connected together internally using the supplied SMB to SMB cables (jumpers) to expand the number of columns in the matrix.

1.3 Warranty information

Warranty information is located on the inside front cover of this manual. Should your Model 7174A require warranty service, contact your Keithley representative or authorized repair facility in your area for further information.

1.4 Manual addenda

Any improvements or changes concerning the matrix card or manual will be explained in an addendum included with the unit. Be sure to note these changes and incorporate them into the manual before using or servicing the unit.

1.5 Safety symbols and terms

The following symbols and terms may be found on an instrument or used in this manual.

The symbol on an instrument indicates that the user should refer to the operating instructions located in the instruction manual.

The symbol on an instrument shows that high voltage may be present on the terminal(s). Use standard safety precautions to avoid personal contact with these voltages.

The **WARNINGS** heading used in this manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the matrix card. Such damage may invalidate the warranty.

1.6 Specifications

Model 7174A specifications may be found at the front of this manual. These specifications are exclusive of the matrix card file specifications, which are located in the Model 707A Switching Matrix manual.

1.7 Unpacking and inspection

1.7.1 Inspection for damage

If you ordered the Model 7174A separately from a system, carefully unpack it from its shipping carton and inspect the card for any obvious signs of physical damage. Report any such damage to the shipping agent immediately. Save the original packing carton for possible future reshipment.

1.7.2 Shipment contents

The following items are included with every Model 7174A order:

- Model 7174A Low Current Matrix Card.
- Model 7174A Instruction Manual.
- Coaxial jumper cables Model CA-121A (8) for matrix expansion.
- Additional accessories as ordered.

1.7.3 Instruction manual

The Model 7174A Instruction Manual is three-hole drilled so that it can be added to the system three-ring binder. After removing the plastic wrapping, place the manual in the binder after the mainframe instruction manual. Note that a manual identification tab is included and should precede the matrix card instruction manual.

If an additional manual is required, order the manual package (Keithley part number 7174A-901-00). The manual package includes an instruction manual and any pertinent addenda.

1.8 Packing for shipment

Should it become necessary to return the Model 7174A for repair, carefully pack the card in its original packing carton or the equivalent, and include the following information:

- Advise as to the warranty status of the matrix card.
- Write ATTENTION REPAIR DEPARTMENT on the shipping label.
- Fill out and include the service form located at the back of this manual.

1.9 Optional accessories

Cables

Model 7078-TRX-3 — A 0.9 m (3 ft.) triaxial cable terminated at both ends with 3-slot male triax connectors. This type of cable is also available in 10 ft. (Model 7078-TRX-10) and 20 ft. (Model 7078-TRX-20) lengths.

Model CA-93-1 — BNC to right angle SMB (coaxial) cable.

Model 7078-CSHP — Is a cable set containing:

Eight 10 ft. (3m) cables — Cables to connect the Model 7174A to a HP-4145 Semiconductor Parameter Analyzer.

Four BNC to triax adapters — Used with eight cables listed above

Four 3 slot triax cables— Cable set to connect the Model 7174A to Source Measurement Units

Four BNC to BNC coax cables — Adapt the measurement and source modules in the HP-4145 to the connectors of the Model 7174A.

Adapters

Model 7078-TRX-TBC — A 3-lug female triax bulkhead connector (with cap). Use this connector for custom applications and interface connections such as test fixtures.

Model 7078-TRX-T — 3-slot male to dual 3-lug female triax tee adapter.

Model 237-BAN-3 — 3-slot male triax to male banana plug.

Model 237-ALG-2 — 3-slot male triax to alligator clips.

Model 7078-TRX-BNC — 3-slot male triax to BNC adapter, connections to center and inner shell. For non-guarded applications, use Model 7078-TRX-GND.

Model 6171 — 3-slot male triax to 2-lug female triaxial adapter.

Tools

Model 9172-314 — A tool designed to remove and install internal coaxial jumpers between adjacent Model 7174A Low Current Matrix Cards.

2
Operation

2.1 Introduction

WARNING

The installation and operation procedures in this section are intended for use only by qualified service personnel. Do not perform these procedures unless qualified to do so. Failure to recognize and observe normal safety precautions could result in personal injury or death.

This section contains information on matrix card connections, installation and matrix programming, and is arranged as follows:

2.2 **Handling precautions** — Discusses precautions that should be taken when handling the card to avoid contamination that could degrade performance.

2.3 **Environmental considerations** — Outlines environmental aspects of using the Model 7174A.

2.4 **Card installation and removal** — Details installation in and removal from the Model 707A Switching Matrix.

2.5 **Connections** — Discusses card connectors, cables and adapters, and typical connections to other instrumentation.

2.6 **Matrix configuration** — Discusses the switching matrix, as well as matrix expansion by connecting two or more cards together.

2.7 **Measurement considerations** — Reviews a number of considerations when making low-level current and capacitance measurements.

2.8 **Coaxial jumper access** — Provides information on jumper removal.

2.2 Handling precautions

To maintain high impedance isolation, care should be taken when handling the matrix card to avoid contamination from such foreign materials as body oils. Such contamination can substantially lower leakage resistance, degrading performance. The areas of the card that are most sensitive to contamination are those associated with Teflon® insulators. To avoid any possible contamination, always grasp the card by the handle or the card edges. Do not touch board surfaces, components, or card edge connectors.

Dirt and other particle build-up over a period of time are other possible sources of contamination. To avoid this problem, operate the mainframe and matrix card only in a clean environment. If contamination is suspected, clean the card as discussed in Section 4.

2.3 Environmental considerations

For rated performance, the card should be operated within the temperature and humidity limits given in the specifications at the front of this manual.

2.4 Card installation and removal

Before making connections, the Model 7174A should be installed within the Model 707A Switching Matrix, as summarized below. Figure 2-1 shows the installation procedure.

WARNING

Turn off the system power before installing or removing matrix cards.

NOTE

The coaxial jumpers used to expand the matrix with two or more Model 7174A cards can not be installed before card insertion; an access door on top of the mainframe allows access to the connectors after the card is installed.

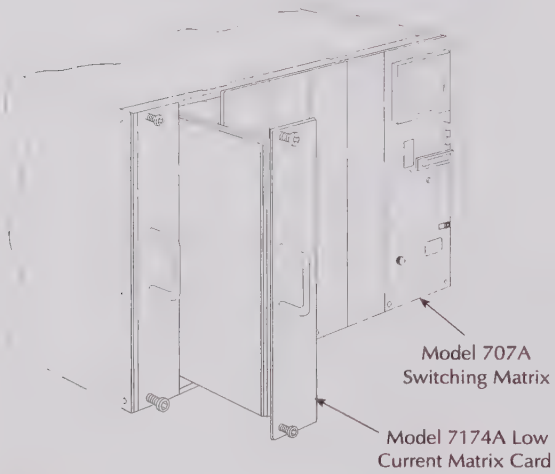


Figure 2-1
Model 7174A installation

1. Before installing the card, make sure the access door on top of the Model 707A Switching Matrix is fully closed and secured. The access door contains tracks for the card slots and must be in place to properly install the card.

CAUTION

Do not touch the card surfaces or any components to avoid contamination that could degrade card performance.

2. With one hand grasping the handle, and the other holding the bottom of the card, line up the card with the tracks in the desired slot. Make certain that the component side of the card is facing the fan on the mainframe.
3. Slide the card into the mainframe until it is properly seated in the edge connectors at the back of the slot. Once the card is properly seated, secure it to the mainframe by finger tightening the spring-loaded screws.

WARNING

The mounting screws must be secured to ensure proper chassis ground connections between the card and the mainframe. Failure to properly secure this ground connection may result in personal injury or death due to electric shock.

4. To remove a card, first turn off the system power. Disconnect all external and internal jumper cables (internal cables can be reached through the access door). Loosen the mounting screws, then pull the card out of the mainframe by the handle. When the back edge of the card clears the mainframe, support it by grasping the bottom edge near the back or back edge.

2.5 Connections

Card connectors, recommended cables and adapters, and typical connections to test instruments are discussed in the following paragraphs.

2.5.1 Card connectors

The card connectors are shown in Figure 2-2. Each pin is equipped with a 3-lug triax connector. As shown in Figure 2-3, the center conductor is signal, the inner shield is guard, and the outer shield is chassis ground.

CAUTION

Do not exceed 200V between any two pins or between any pin and chassis.

The Model 7174A has 12 columns (labeled 1 through 12) and 8 rows (labeled A through H).

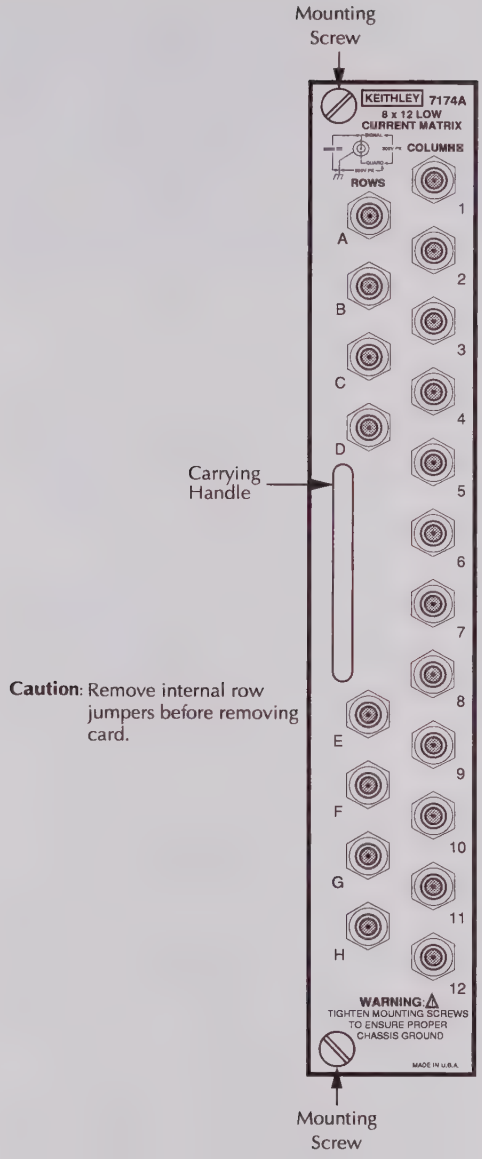


Figure 2-2
Card connectors

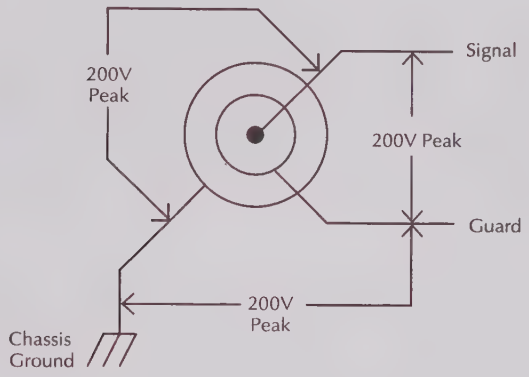


Figure 2-3
Triax connector configuration

2.5.2 Recommended cables and adapters

Table 2-1 summarizes the cables recommended for use with the Model 7174A. Equivalent user-supplied items may be substituted as long as they are of sufficient quality (low offset current, high leakage resistance). Using substandard cables and connectors may degrade the integrity of the measurements made. See paragraph 2.7 for a discussion of measurement considerations.

Table 2-1
Recommended cables and adapters

Model	Description
7078-TRX-x	3-slot male triax connectors on both ends (x=3, 10 or 20 ft.)
237-BAN-3	3-slot male triax to male banana plug
237-ALG-2	3-slot male triax to alligator clips
7078-TRX-BNC	3-slot male triax to BNC adapter, connections to center and inner shell
7078-TRX-GND	3-slot male triax to BNC adapter, connections to center and outer shell
7078-TRX-T	3-slot male to dual 3-lug female triax tee adapter
6171	3-slot male triax to 2-lug female triax adapter
CA-93-1	BNC to right angle SMB cable

2.5.3 Triax banana plug adapter

For instruments that use banana jacks, you need a triax cable terminated with a 3-slot male triax and a single banana plug. Use the Model 237-BAN-3 or prepare a special cable as outlined below **(Special triax to banana plug cable preparation)** using the parts listed in Table 2-2.

Table 2-2
Parts for special triaxial cable

Keithley part or model number	Description
7078-TRX-3 triax cable*	Triax cable terminated with 3-slot male triax connectors
BG-10-2	Red banana plug

*One connector must be cut off

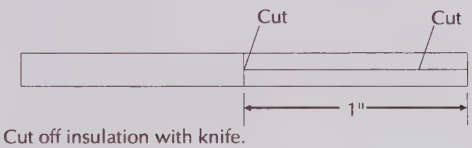
Figure 2-4 shows the conductors and insulation layers of a triaxial cable. These layers must be carefully stripped back, cleaned thoroughly and insulated with high insulation resistance material such as Teflon® to maintain the integrity of the cable and measurement system. With the Model 237-BAN-3, the center conductor of the triax is connected to the banana plug. The inner and outer shields have no connection. With the special cable shown in Figure 2-4, the inner shield is shorted to the center conductor. Which cable to use depends on your application. The length of unshielded conductor that is connected to the banana plug should be minimized to maintain signal integrity. The topic of signal integrity is also discussed in paragraph 2.7 Measurement considerations.

Note that you can use either an unterminated triax cable, or cut a dual-connector cable (7078-TRX-10) in half to construct two special cables.

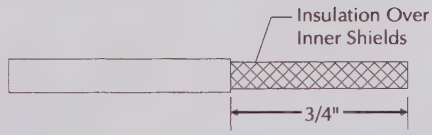
Special triax to banana plug cable preparation

The following steps outline a procedure for installing a banana plug on the end of a triaxial cable (with inner shield shorted to center conductor).

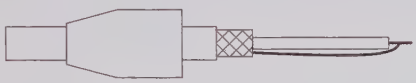
1. Using a knife, cut and strip back the jacket about 1-1/2 inches.
2. Remove the outer insulation, then cut away the outer shield as far as the insulation is stripped as shown in Figure 2-4(A).
3. Carefully strip away the insulation over the inner shield one inch, then cut the inner shield and guard wire off even with the stripped insulation as shown in Figure 2-4(B).
4. Strip the insulator back 1/2 inch, then twist the strands of the conductor together as shown in Figure 2-4(C).
5. Unscrew the cover from a banana plug, then slide the cover over the conductor.
6. Insert the stripped center conductor through the hole in the body of the banana plug, then wrap the wire around the plug body as shown in Figure 2-4(D).
7. Screw on the plastic cover as shown in Figure 2-4(E). Make certain the wire is secure by gently pulling on the plug.



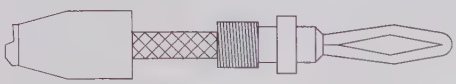
(A) Cut off insulation with knife.
Cut off outer shield.



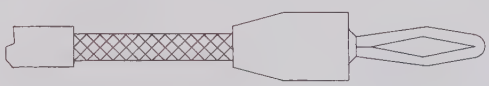
(B) Strip insulation off inner shield.



(C) Twist inner shield then strip inner conductor.
Twister inner shield and center conductor together, slip on plastic cover.



(D) Insert wires into hole and wrap around body.



(E) Screw on plastic cover.

Figure 2-4
Triax cable preparation

2.5.4 General instrument connections

The following paragraphs discuss connecting the Model 7174A to various general classes of instrumentation such as DMMs, electrometers, sources, and source/measure units. Because these configurations are generic in nature, some modification of the connecting schemes may be necessary for your particular instrumentation. Also, special cables or adapters may be necessary. In all cases, 3-lug triax cables must be used to make the connections.

WARNING

Do not use coaxial cables and adapters because hazardous voltage from guard sources may be present on the cable shields.

Figure 2-5 shows the general instrument connections for the discussions below. Note that DUT guarding or shielding are not included here; see Figures 2-22 and 2-23 for shielding and guarding information. As shown, all figure assume instruments are connected to rows, and the DUT is connected to columns.

DMM connections

General DMM connections are shown in Figure 2-5 (A), (B), and (C). Floating connections are shown in (A) with LO and HI routed to two separate jacks on the Model 7174A. The common LO connections in (Figure 2-5B) should be used only for non-critical applications because the performance of the GUARD pathway is not specified.

WARNING

Hazardous voltage from other guard sources may be present on LO or the DUT if other crosspoints are closed.

4-wire DMM connections are shown in Figure 2-5(C). In this case, a total of four jacks are required; HI, LO, SENSE HI, and SENSE LO.

Electrometer connections

Typical electrometer connections are shown in Figure 2-5(D) through (G). The unguarded volts connections in (D) show the HI signal path routed through one jack, and the LO path goes through the other connector. Both GUARD pathways are connected to electrometer LO. For guarded voltage (E), Model 7174A GUARD is connected to electrometer GUARD.

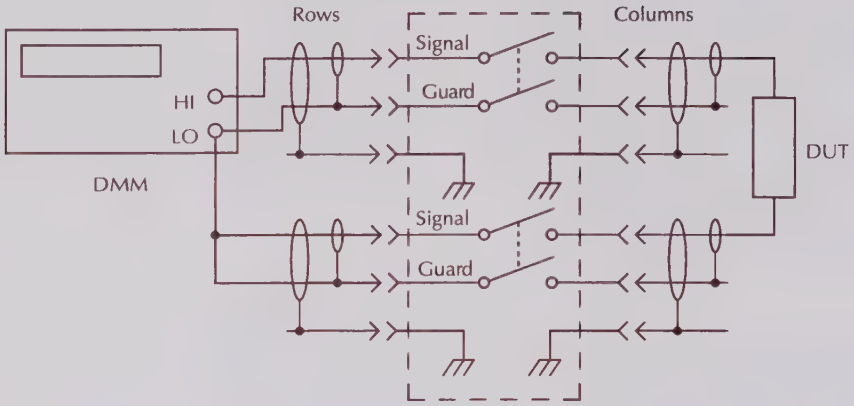
The connections for electrometer fast amps and resistance measurements are shown in Figure 2-5(F) and (G). These configurations are essentially the same as those discussed above. For the case of fast amps, both GUARD paths are connected to electrometer LO, while in the case of guarded resistance, one GUARD path is connected to electrometer GUARD, and the other GUARD path is connected to electrometer LO.

Source connections

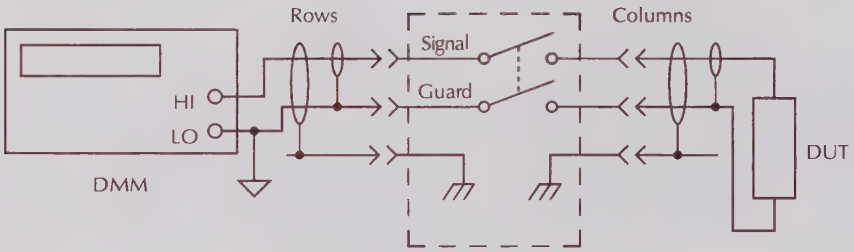
Voltage and current source connections are shown in Figure 2-5(H) through (J). The HI and LO paths of the voltage source (H) are routed through two jacks, with both card GUARD pathways connected to voltage source LO. For the unguarded current source connections (I), card GUARD is again connected to source LO, with source HI and LO routed through two pathways. In the case of the guarded current source in (J), card GUARD of the HI signal path is connected to source GUARD, and the other GUARD path is connected to source LO.

Source/measure unit connections

Figure 2-5(K) shows typical connections for a source/measure unit (SMU). In this instance, a remote-sensing type of a SMU is shown, requiring a total of four signal pathways to the DUT. For critical measurements, both source and sense HI pathways would be guarded as shown, with two of the four card GUARD pathways connected to SMU GUARD terminals. As with other instrument connections, the LO card GUARD pathways are connected to SMU LO terminals.



A.) DMM Floating

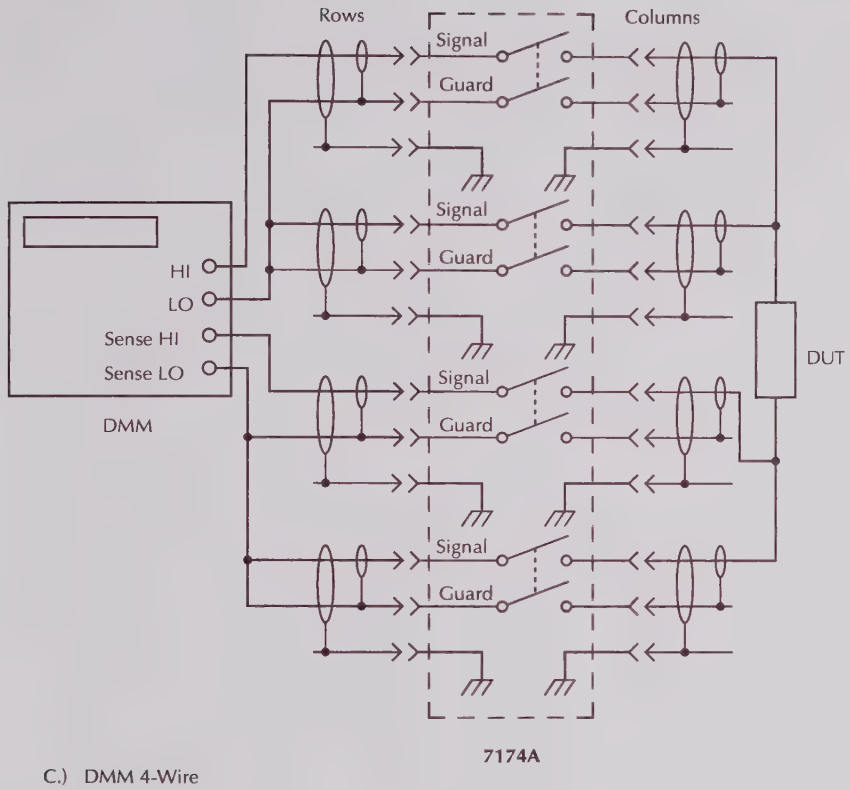


Warning: Hazardous voltage from guard sources may be present on LO.

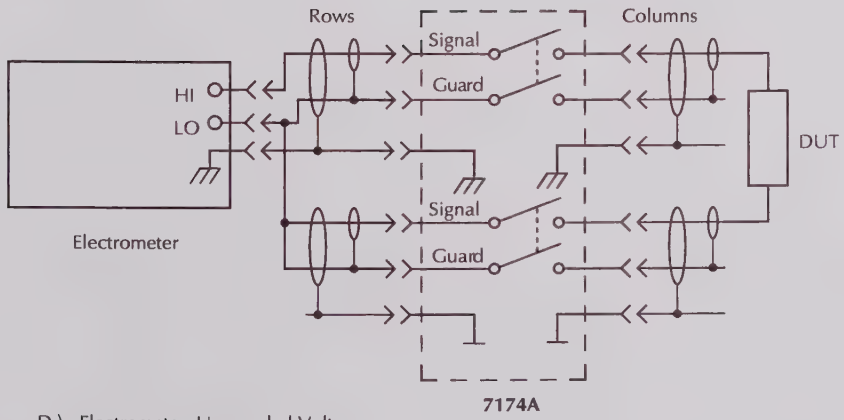
Note: Use this configuration only for non-critical measurements.

B.) DMM Common LO

Figure 2-5
General instrument connections

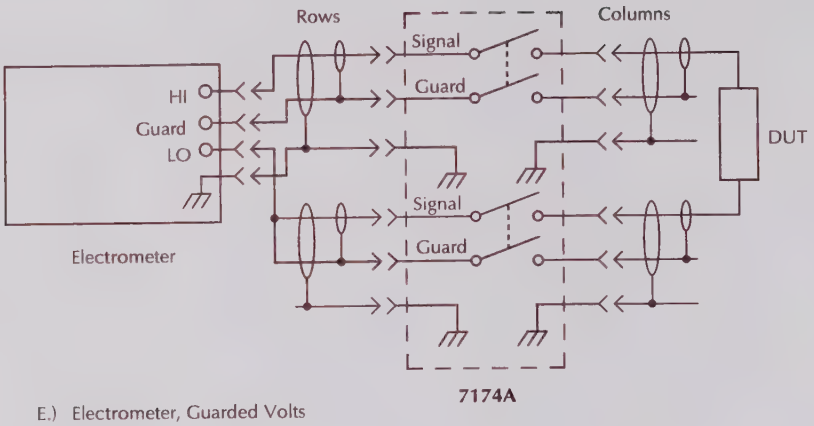


C.) DMM 4-Wire

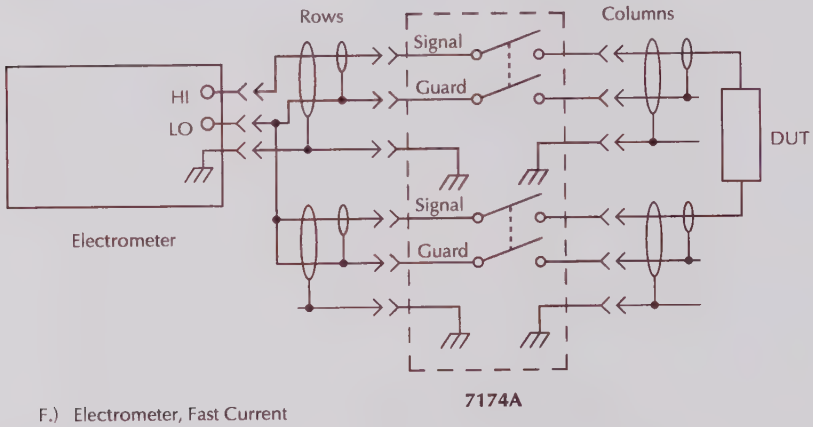


D.) Electrometer, Unguarded Volts

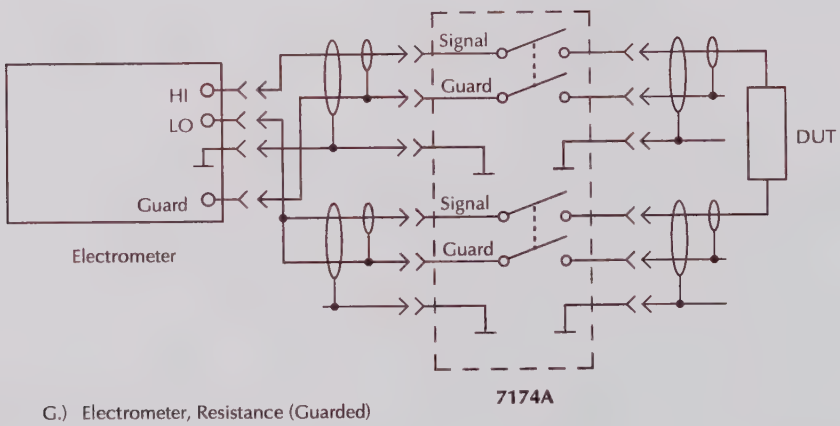
Figure 2-5
General instrument connections (cont.)



E.) Electrometer, Guarded Volts

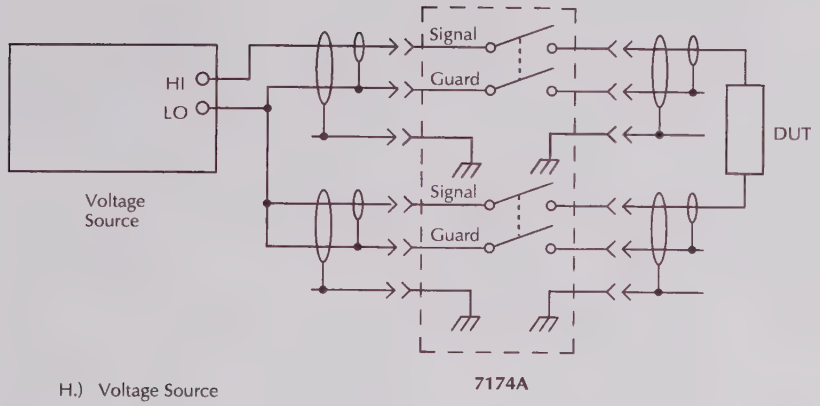


F.) Electrometer, Fast Current

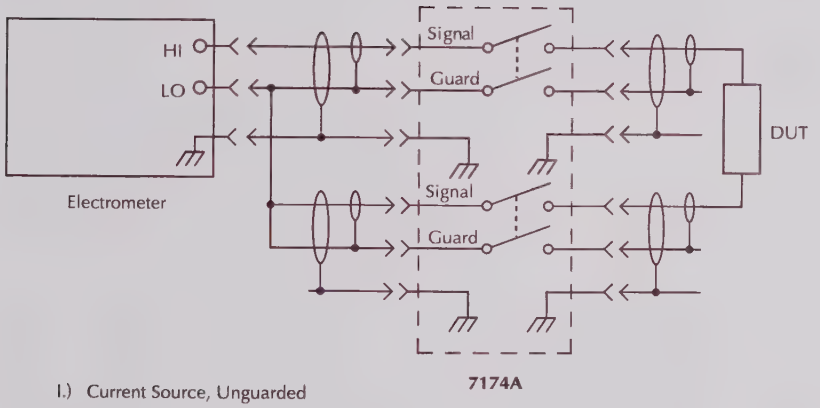


G.) Electrometer, Resistance (Guarded)

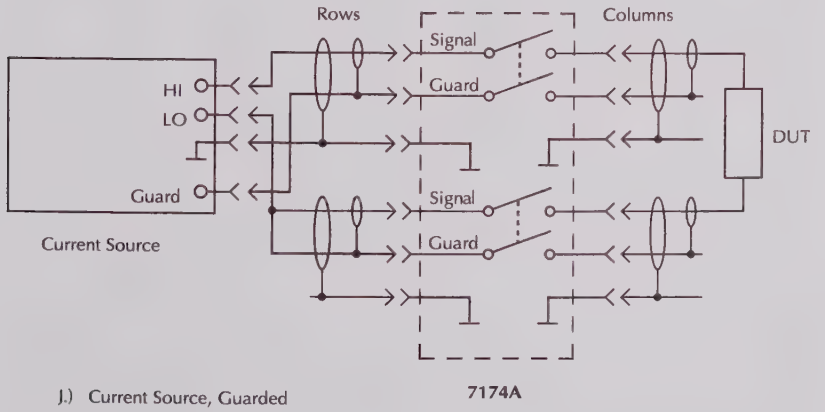
Figure 2-5
General instrument connections (cont.)



H.) Voltage Source

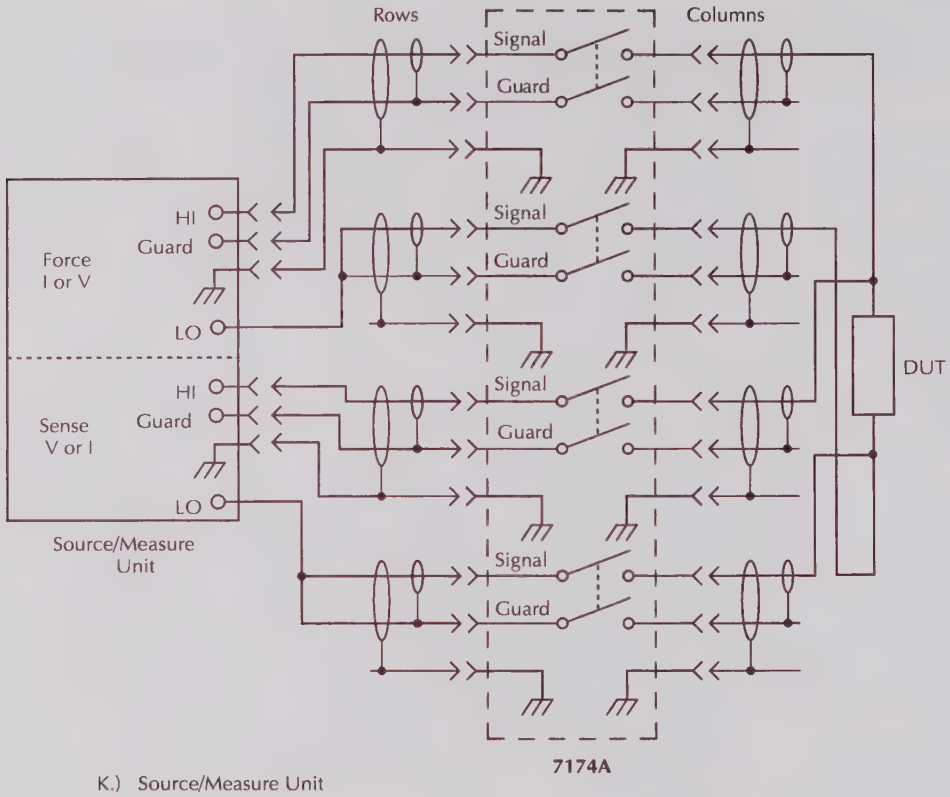


I.) Current Source, Unguarded



J.) Current Source, Guarded

Figure 2-5
General instrument connections (cont.)



K.) Source/Measure Unit

Note: DUT shielding/guarding not shown. See Figures 2-20 and 2-21.

Figure 2-5
General instrument connections (cont.)

2.5.5 Keithley instrument connections

The following paragraphs outline connecting typical Keithley instruments to the Model 7174A 8 × 12 Low Current Matrix Card. Other similar instruments can be connected using the same cabling as long as their input/output configurations are the same. Instrument connections covered include:

- Model 617 Electrometer/Source
- Model 196 DMM
- Model 230 Programmable Voltage Source
- Model 220 Programmable Current Source
- Model 590 CV Analyzer
- Model 236/237/238 Source Measure Unit

Model 617 electrometer connections

Connections for the Model 617 Electrometer are shown in Figure 2-6. The electrometer INPUT and COM can be connected to any row. Figure 2-6 shows connections to rows A and B.

1. Connect one end of a Model 7078-TRX- (3, 10, or 20) 3-lug triaxial cable to row A of the Model 7174A.
2. Connect the other end of the triax cable to the Model 617 INPUT connector using a Model 6172 adapter.
3. Connect the triax end of a triax/banana cable to row B of the Model 7174A.
4. Connect the banana plug end of the triax/banana cable to the COM terminal of the Model 617. The shorting link between COM and chassis ground should be removed for this application.
5. Place the GUARD switch in the OFF position.
6. To connect the voltage source to the Model 7174A, connect the V-SOURCE HI and LO connector of the Model 617 to the desired row connectors on the matrix card. Figure 2-6 shows connections to rows C and D.

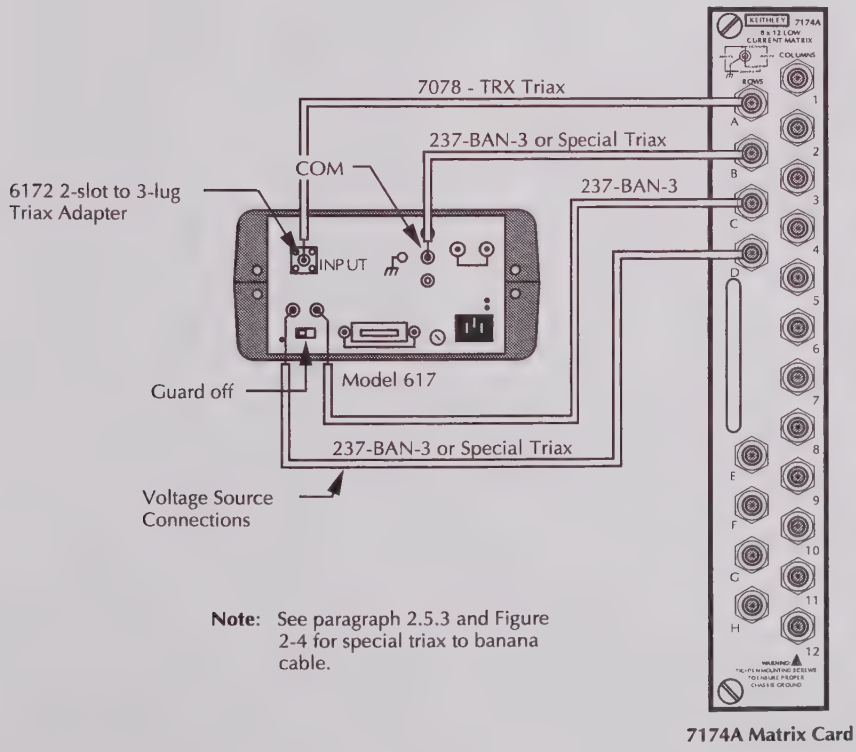


Figure 2-6
Model 617 electrometer connections

Model 196 DMM connections

Connect the Model 196 or other similar DMM to the matrix card using the general configuration shown in Figure 2-7. The VOLTS OHMS HI and LO terminals should be connected to the desired rows using triax/banana cables. For 4-wire ohms measurements, the OHMS SENSE HI and LO terminals should be connected to two additional rows using the same type of cables.

NOTE

For low-level voltage measurements, connect the inner shield of the HI cable to VOLT OHMS LO to minimize noise.

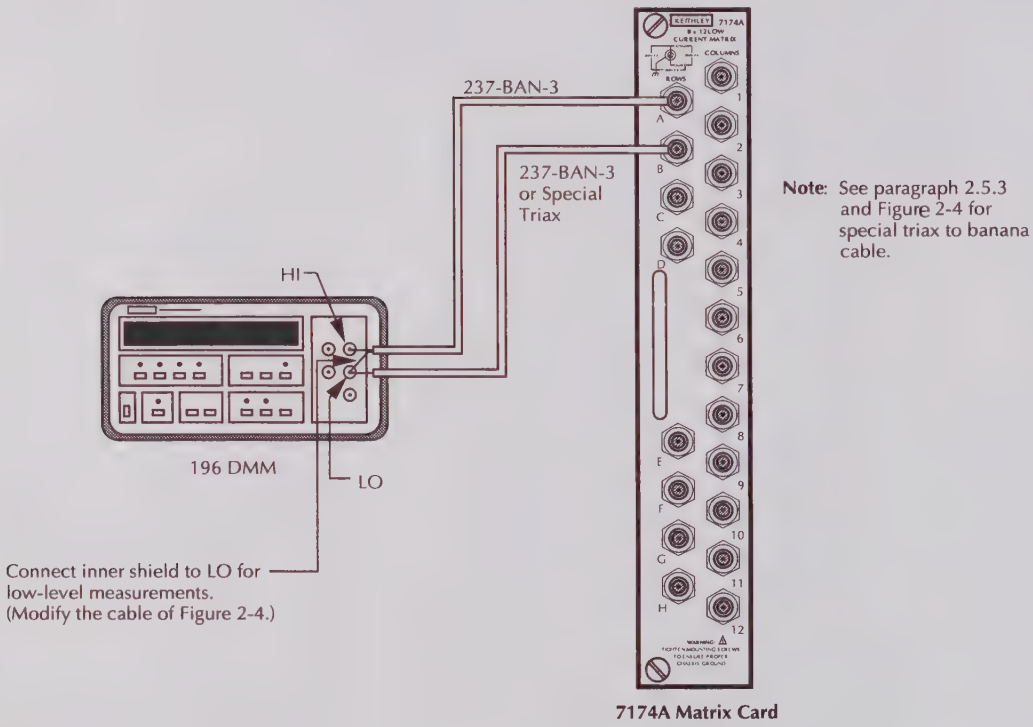


Figure 2-7
Model 196 DMM connections

Model 230 voltage source connections

Connect the Model 230 OUTPUT and COMMON terminal to the desired rows using triax/banana plug cables, as shown in Figure 2-8. For remote sensing applications, the SENSE OUTPUT and SENSE COMMON connectors can be routed through two additional rows using similar cables.

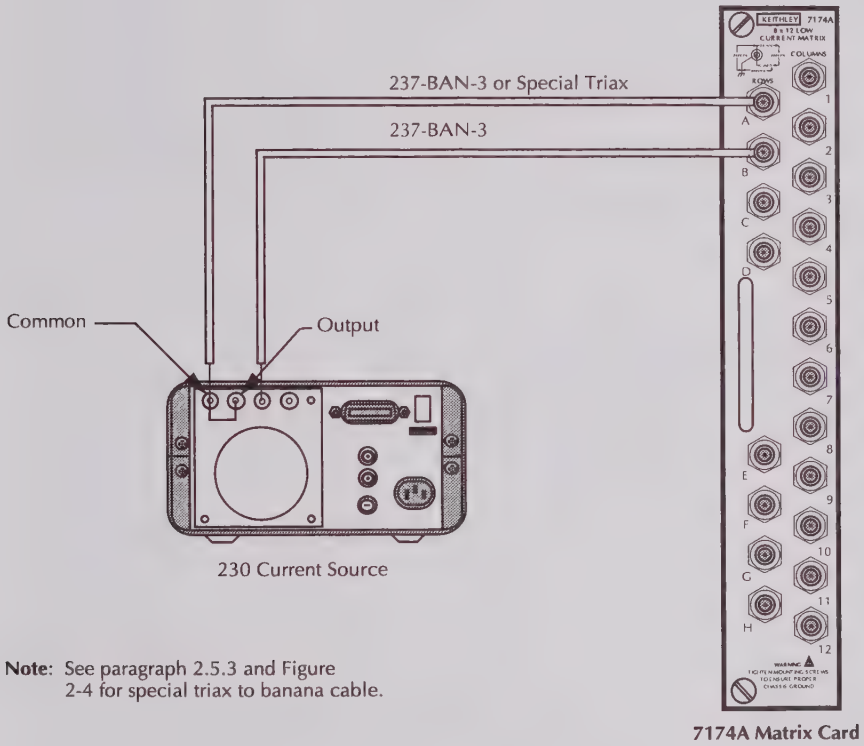


Figure 2-8
Model 230 voltage source connections

Model 590 CV analyzer connections

The Model 590 CV analyzer can be connected to any row or any column as shown in Figure 2-9. The BNC cables that are supplied with the Model 590 can be used; however, Model 7078-TRX-BNC adapters must be used at the Model 7174A end.

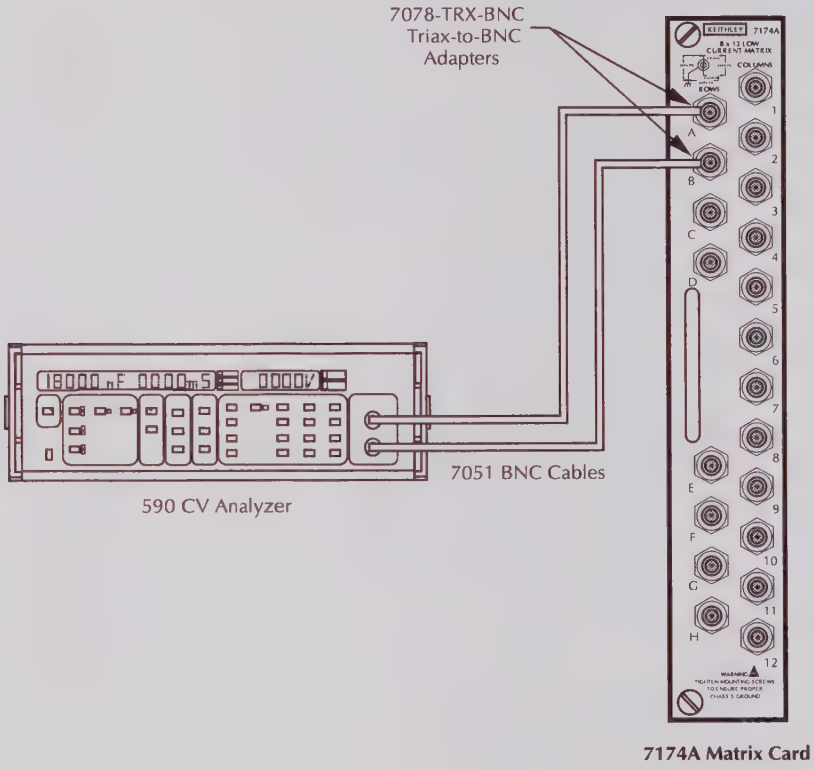


Figure 2-9
Model 590 CV analyzer connections

Model 220 current source connections

The Model 220 current source can be connected to the matrix card using the Model 6167 Guarded Adapter, as shown in Figure 2-10. This configuration guards the output signal to minimize the effects of distributed capacitance and leakage current.

NOTE

The Model 6167 adapter must be modified by internally disconnecting the inner shield connection of the input jack from the GUARDED/UNGUARDED selection switch. Otherwise, instrument LO will be connected to chassis ground through the adapter.

1. Connect the Model 6167 adapter to the Model 220 OUTPUT jack.
2. Connect a Model 7078-TRX-(3, 10 or 20) triax cable between the guarded adapter and the desired row of the Model 7174A.
3. Connect the Model 220 GUARD output to GUARD INPUT terminal of the adapter.
4. Connect the triax end of a triax/banana cable to the desired row on the Model 7174A.
5. Connect the banana plug end of the triax/banana cable to the OUTPUT COMMON jack of the Model 220.

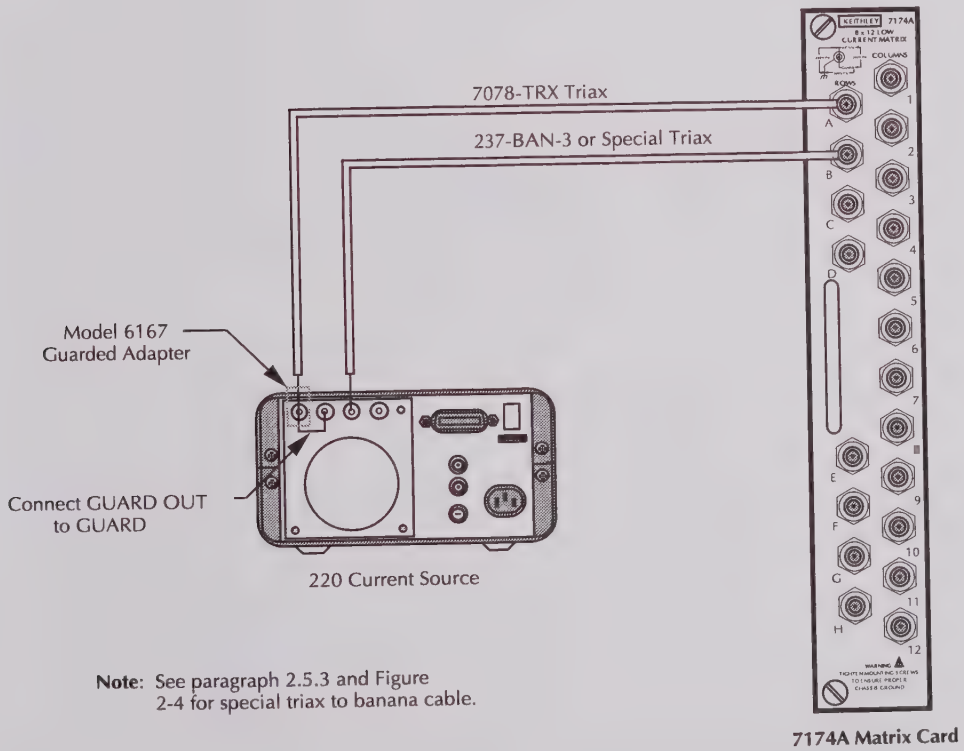


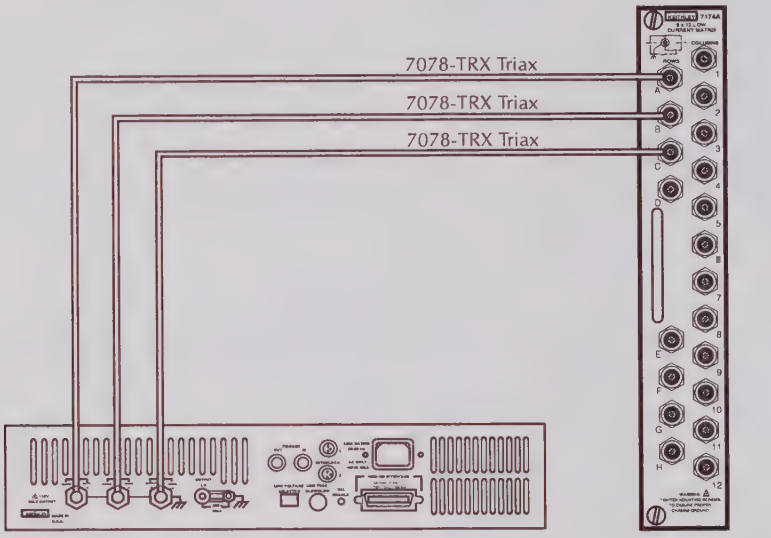
Figure 2-10
Model 220 current source connections

Model 236/237/238 source measure unit connections

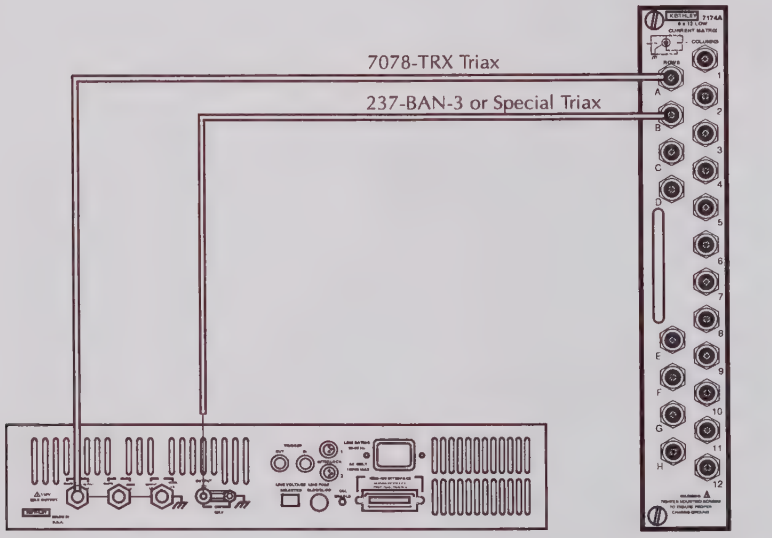
Source measure units are connected to the matrix card using Model 7078-TRX cables. A Model 237-BAN-3 triax/banana cable can also be used to connect the output low binding post on the source measure unit to the matrix. Figure 2-11 shows connections for remote and local sensing applications.

CAUTION

Models 237 and 238 source measure units can only be used within the specified maximum signal levels of the Model 7174A (200V, 2A).



A. Remote Sensing



B. Local Sensing

Caution: The models 237 and 238 Source Measure Units can only be used within the specified maximum signal levels of the Model 7174A (200V, 2A carry).

Figure 2-11
Model 236/237/238 source measure unit connections

2.5.6 Typical test fixture connections

Typically, one or more test fixtures will be connected to desired columns of the Model 7174A. Typically, the test fixtures will be equipped with card-edge connectors with wires soldered to them. In some cases, the test fixture will be equipped with triax connectors; for those types, Keithley Model 7078-TRX-(3, 10, or 20) cables can be used, as shown in Figure 2-12.

WARNING

Do not use BNC cables and adapters in cases where hazardous voltages from guard sources could be present on the BNC cable shields.

Internally, the test fixture should be wired as shown in the equivalent circuit of Figure 2-13. SIGNAL should be connected to the probe or other device contact points, while GUARD should be carried through as close to the device as possible. If coaxial probes are to be used, connect GUARD to the probe shield if the probe shield is insulated from the fixture shield.

Usually, the chassis ground terminal of the triax connector will automatically make contact with the fixture shield by virtue of the mounting method. However, ground integrity should be checked to ensure continued protection against hazardous guard voltages.

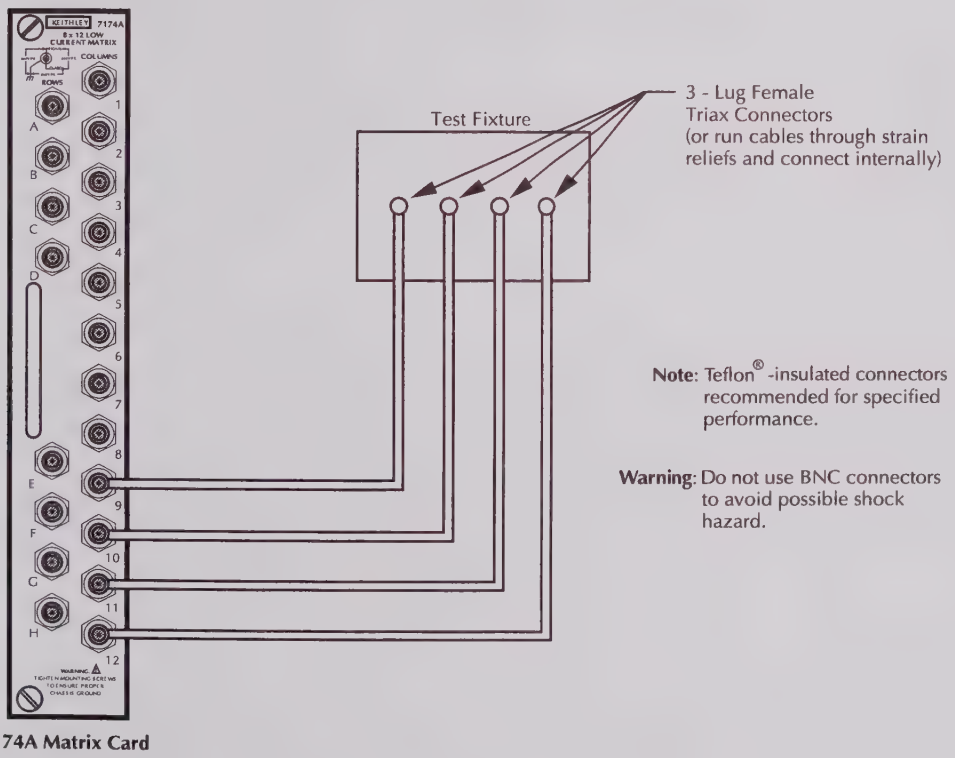


Figure 2-12
Typical test fixture connections

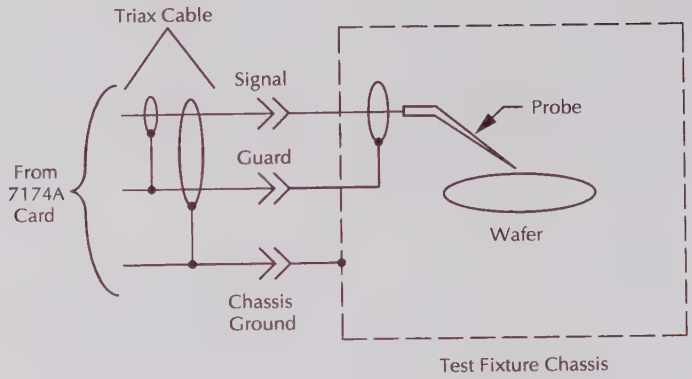


Figure 2-13
Equivalent circuit of test fixture connections

2.6 Matrix configuration

This section describes the matrix configuration of the Model 7174A. It also explains ways to expand the matrix by installing and connecting additional matrix cards in the Model 707A Switching Matrix.

2.6.1 Switching matrix

As shown in Figure 2-14, the Model 7174A is organized as an 8 x 12 (8 rows by 12 columns) matrix. The rows on the card are labeled A through H while the columns are numbered 1 through 12. The actual column number to use when programming depends on the slot and unit number (Table 2-3). For example, card column number 2 on a card in slot 5 of unit 1 is accessed as matrix column 50.

Each intersecting point in the matrix is called a crosspoint that can be individually closed or opened by programming the Model 707A mainframe. By closing the appropriate crosspoint, required pathways and pins may be connected. All crosspoints are configured for 2-pole switching, as shown in Figure 2-14. SIGNAL and GUARD are switched separately to any of the 12 columns on the card.

2.6.2 Path isolators

The path isolator relay switches shown in Figure 2-14 serve to isolate a given path from the rest of the matrix when no crosspoint (relay) is closed in that pathway. This topology minimizes leakage current and capacitance to pathways which are active. These isolators close automatically when any crosspoint on the path is closed and open automatically when all crosspoints on the path are opened.

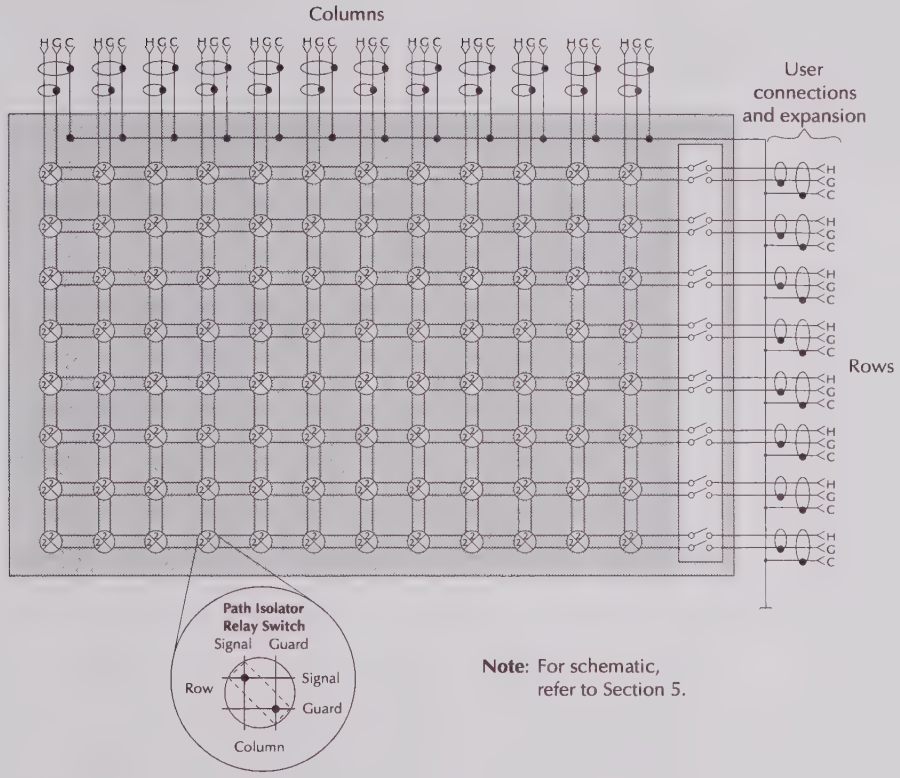


Figure 2-14
Matrix configuration

Table 2-3
Column numbering by slot and unit

Unit	Slot	Columns (1 through 12)											
1	1	1	2	3	4	5	6	7	8	9	10	11	12
	2	13	14	15	16	17	18	19	20	21	22	23	24
	3	25	26	27	28	29	30	31	32	33	34	35	36
	4	37	38	39	40	41	42	43	44	45	46	47	48
	5	49	50	51	52	53	54	55	56	57	58	59	60
	6	61	62	63	64	65	66	67	68	69	70	71	72
2	1	73	74	75	76	77	78	79	80	81	82	83	84
	2	85	86	87	88	89	90	91	92	93	94	95	96
	3	97	98	99	100	101	102	103	104	105	106	107	108
	4	109	110	111	112	113	114	115	116	117	118	119	120
	5	121	122	123	124	125	126	127	128	129	130	131	132
	6	133	134	135	136	137	138	139	140	141	142	143	144
3	1	145	146	147	148	149	150	151	152	153	154	155	156
	2	157	158	159	160	161	162	163	164	165	166	167	168
	3	169	170	171	172	173	174	175	176	177	178	179	180
	4	181	182	183	184	185	186	187	188	189	190	191	192
	5	193	194	195	196	197	198	199	200	201	202	203	204
	6	205	206	207	208	209	210	211	212	213	214	215	216
4	1	217	218	219	220	221	222	223	224	225	226	227	228
	2	229	230	231	232	233	234	235	236	237	238	239	240
	3	241	242	243	244	245	2446	247	248	249	250	251	252
	4	253	254	255	256	257	258	259	260	261	262	263	264
	5	265	266	267	268	269	270	271	272	273	274	275	276
	6	277	278	279	280	281	282	283	284	285	286	287	288
5	1	289	290	291	292	293	294	295	296	297	298	299	300
	2	301	302	303	304	305	306	307	308	309	310	311	312
	3	313	314	315	316	317	318	319	320	321	322	323	324
	4	325	326	327	328	329	330	331	332	333	334	335	336
	5	337	338	339	340	341	342	343	344	345	346	347	348
	6	349	350	351	352	353	354	355	356	357	358	359	360

2.6.3 Internal matrix expansion

Two to six Model 7174A cards can be connected together within the mainframe to yield an 8 × N matrix, where N depends on the number of cards. Figure 2-15 shows an internally expanded matrix with three cards, resulting in an 8 × 36 (eight row by 36 column) matrix. As summarized in Table 2-3, the actual column number used when programming the unit is determined by the slot.

WARNING

The shells of the row jumpers are at guard potential. To avoid a possible shock hazard, always disconnect all cables from the row and column jacks before removing or installing jumpers.

Because of critical signal paths, rows A-H are not jumpered through the backplane. Instead, install the supplied coaxial jumpers between appropriate connectors on Model 7174A cards (for more critical signal paths, rows can be isolated from other cards by not installing these cables). Each card has two coaxial connectors for each row, allowing daisy chaining of card rows. These connectors can be reached by lifting the access door on the top of the mainframe; do not remove cards to install the jumpers. This expansion is shown schematically in Figure 2-15 for cards located in slots 1, 2 and 3.

Figure 2-16 shows the location of the connectors used for this expansion. These connectors can be reached by lifting the access door on the top of the Model 707A Switching Matrix. The jumpers must be installed and removed before installing or removing a Model 7174A from the 707A Switching Matrix. Figure 2-17 shows how two cards can be daisy chained together using the coaxial jumpers.

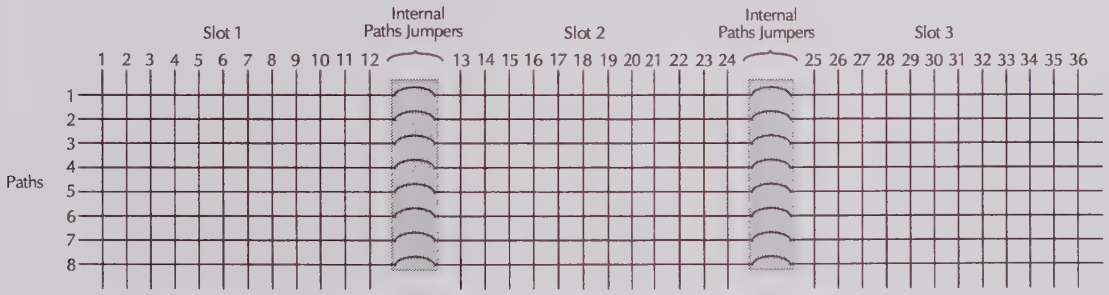


Figure 2-15
Connecting three cards for an 8 × 36 matrix

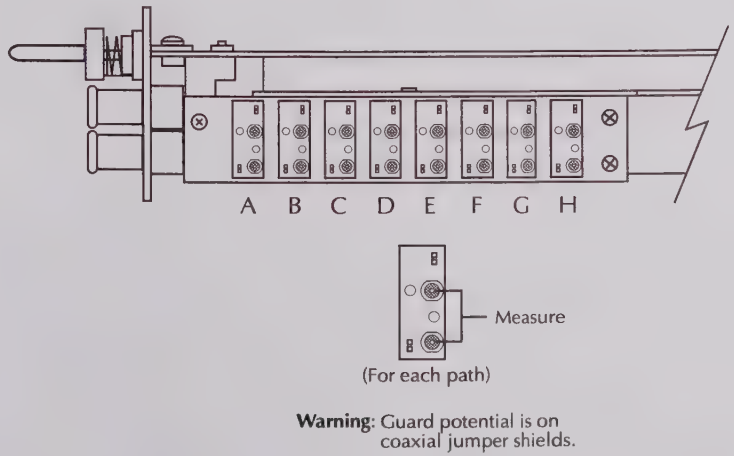


Figure 2-16
Jumper connector locations

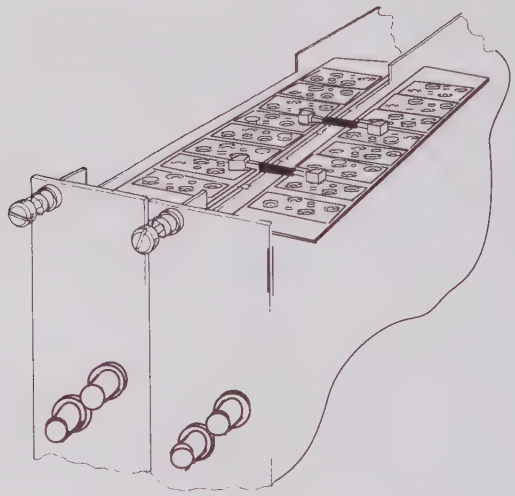


Figure 2-17
Two cards in daisy chain configuration

2.7 Measurement considerations

Most measurements made with the Model 7174A concern low-level signals. Such measurements are subject to various types of noise that can seriously affect low-level measurement accuracy. The following paragraphs discuss possible noise sources that might affect these measurements.

2.7.1 Magnetic fields

When a conductor cuts through magnetic lines of force, a very small current is generated. This phenomenon will frequently cause unwanted signals to occur in the test leads of a switching matrix system. If the conductor has sufficient length, even weak magnetic fields like those of the earth can create sufficient signals to affect low-level measurements.

Two ways to reduce these effects are: (1) reduce the lengths of the test leads, and (2) minimize the exposed circuit area. In extreme cases, magnetic shielding may be required. Special metals with high permeability at low flux densities (such as mu metal) are effective at reducing these effects.

Even when the conductor is stationary, magnetically-induced signals may still be a problem. Fields can be produced by various signals such as the AC power line voltage. Large inductors such as power transformers can also generate substantial magnetic fields, so care must be taken to keep the switching and measuring circuits a good distance away from these potential noise sources.

2.7.2 Electromagnetic Interference (EMI)

The electromagnetic interference characteristics of the Model 7174A comply with the electromagnetic compatibility (EMC) requirements of the European Union (EU) directives as denoted by the CE mark. However, it is still possible for sensitive signals to be affected by external sources. In these instances, special precautions may be required in the test setup.

Sources of EMI include:

- Radio and TV broadcast transmitters.
- Communications transmitters, including cellular phones and handheld radios.
- Devices incorporating microprocessors and high-speed digital circuits.
- Impulse sources as in the case of arcing in high-voltage environments.

The Model 7174A, signal source, measuring instrument, and signal leads should be kept as far away as possible from any EMI sources. Additional shielding of the card, signal leads, sources, and measuring instruments will often reduce EMI to an acceptable level. In extreme cases, a specially constructed screen room may be required to sufficiently attenuate the troublesome signal.

Many instruments incorporate internal filtering that may help to reduce EMI effects in some situations. In other cases, additional external filtering may be required. Keep in mind, however, that filtering may have detrimental effects, such as increased settling time, on the measurement.

2.7.3 Ground loops

When two or more instruments are connected together, care must be taken to avoid unwanted signals caused by ground loops. Ground Loops usually occur when sensitive instrumentation is connected to other instrumentation with more than one signal return path such as power line ground. As shown in Figure 2-18, the resulting ground loop causes unwanted signals to flow through the instrument LO signal leads and then back through power line ground. This circulating current develops a small but undesirable voltage between the LO terminals of the two instruments. This voltage will be added to the source voltage, affecting the accuracy of the measurement.

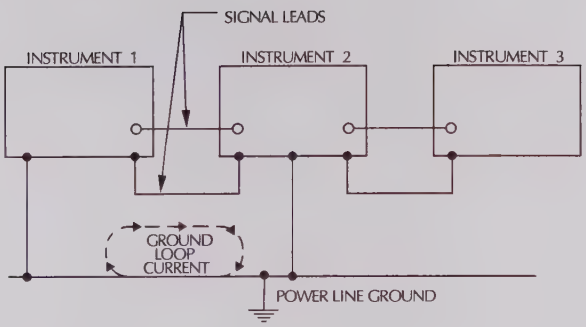


Figure 2-18
Power line ground loops

Figure 2-19 shows how to connect several instruments together to eliminate this type of ground loop problem. Here, there is only one connection to power line ground.

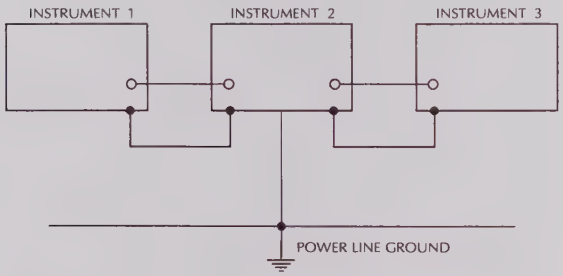


Figure 2-19
Eliminating ground loops

Ground loops are not normally a problem with instruments having isolated LO terminals. However, all instruments in the test setup may not be designed in this manner. When in doubt, consult the manual for each instrument in the test setup.

2.7.4 Keeping connectors clean

As is the case with any high-resistance device, the integrity of connectors can be damaged if they are not handled properly. If the connector insulation becomes contaminated, the insulation resistance will be substantially reduced, affecting high-impedance measurement paths.

Oils and salts from the skin can contaminate connector insulators, reducing their resistance. Also, contaminants present in the air can be deposited on the insulator surface. To avoid these problems, never touch the connector insulating material. In addition, the matrix card should be used only in clean, dry environments to avoid contamination.

If the connector insulators should become contaminated, either by inadvertent touching or from air borne deposits, they can be cleaned with a cotton swab dipped in clean methanol or an HCFC. After thorough cleaning, they should be allowed to dry for several hours in a low-humidity environment before use, or they can be dried more quickly using dry nitrogen.

2.7.5 Noise currents caused by cable flexing

Noise currents can be generated by bending or flexing coaxial, triaxial, or quadraxial cables. Such currents, known as triboelectric currents, are generated by charges created between a conductor and insulator caused by friction.

Low-noise cable can be used to minimize these effects. Such cables have a special graphite coating under the shield to provide lubrication and to provide a conduction path to equalize charges.

Even low-noise cable generates some noise current when flexed or subjected to vibration. To minimize these effects, keep the cables as short as possible, and do not subject them to temperature variations that could cause expansion or contraction. Tie down offending cables securely to avoid movement, and isolate or remove vibration sources such as motors or pumps.

2.7.6 Shielding

Proper shielding of all unguarded signal paths and devices under test is important to minimize noise pickup in virtually any switching matrix system. Otherwise, interference from such noise sources as line frequency and RF fields can seriously corrupt a measurement.

In order for shielding to be effective, the shield must completely surround the source, measure and guard signals. It must also have a low impedance path to chassis ground. This is shown pictorially in Figure 2-20. The shield also functions as a safety shield since it is connected to chassis ground.

WARNING

Hazardous voltage may be present if LO on any instrument is floated above ground potential.

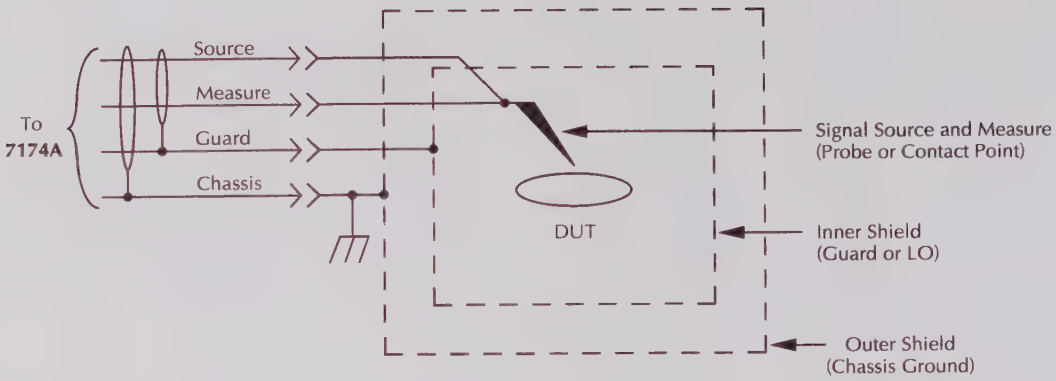


Figure 2-20
Shielded and guarded

2.7.7 Guarding

Guarding is important in high-impedance circuits where leakage resistance and capacitance could have degrading effects on the measurement. Guarding consists of using a shield surrounding a conductor that is carrying the high impedance signal. This shield is driven by a low-impedance amplifier to maintain the shield at signal potential.

Guarding minimizes leakage resistance effects by driving the cable shield with a unity gain amplifier, as shown in Figure 2-21. Since the amplifier has a high input impedance, it minimizes loading on the high-impedance signal lead. Also, the low output impedance ensures that the shield remains at signal potential, so that virtually no leakage current flows through the leakage resistance, R_L. Leakage between inner and outer shields may be considerable, but that leakage is of little consequence because that current is supplied by the buffer amplifier rather than the signal itself.

In a similar manner, guarding also reduces the effective cable capacitance, resulting in much faster measurements on high-impedance circuits. Because any distributed capacitance is charged through the low impedance of the buffer amplifier rather than by the source, settling times are shortened considerably by guarding.

In order to use guarding effectively with the Model 7174A, the guard path of the matrix card should be connected to the guard output of the sourcing or measuring instrument. Figure 2-20 shows typical connections. Guard should be properly carried through the inner shield to the device under test to be completely effective. The shielded, guarded test fixture arrangement shown in Figure 2-20 is also recommended for safety purposes (guard voltage may be hazardous with some instruments).

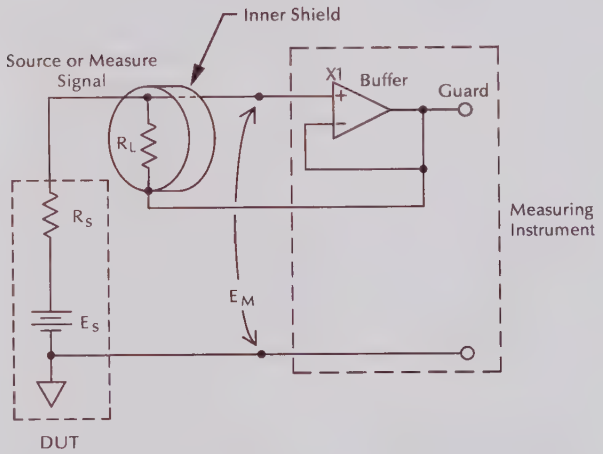


Figure 2-21
Guarded circuit

2.7.8 Matrix expansion effects on card specifications

Specifications such as those given for path isolation and offset current are with a single Model 7174A card installed in the mainframe. Expanding the matrix by internally connecting two or more Model 7174A cards together will degrade system performance specifications (other types of cards do not affect the specifications because they use different pathways in the mainframe backplane). The extent depends on how many cards are used, as well as the amount of cabling used to connect them together.

With internal pathway expansion, isolation among paths is increased, and offset current is decreased, although the isolator relays on the card do help to minimize these effects.

2.8 Coaxial jumper access

To gain access to jumpers, lift jumper across cover (Figure 2-22).

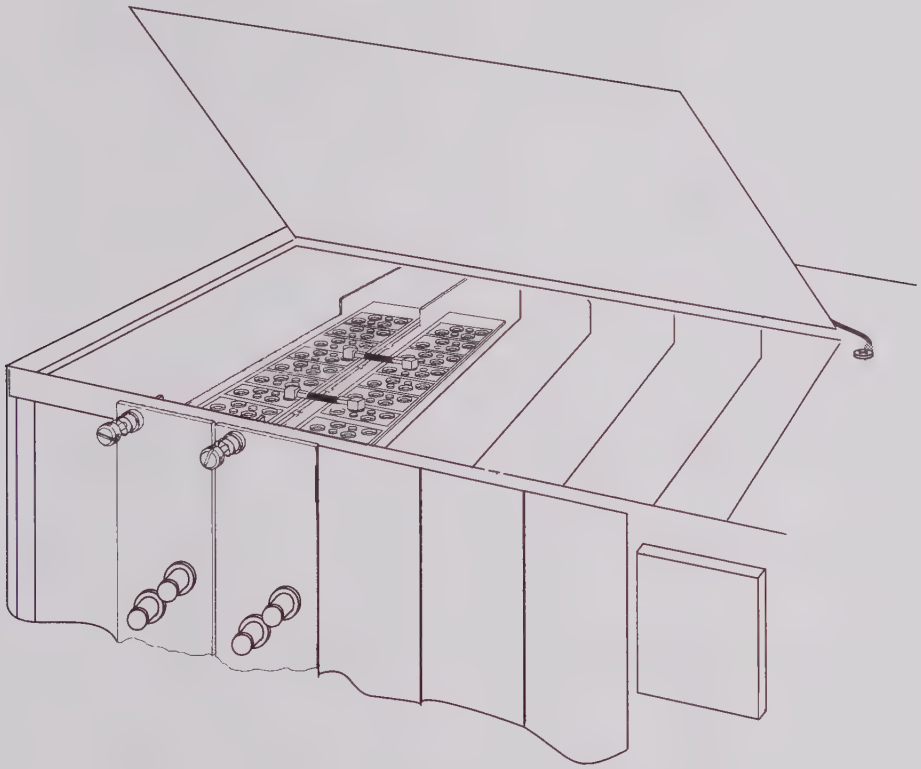


Figure 2-22
Coaxial jumper access

3
Applications

3.1 Introduction

This section covers typical applications for the Model 7174A 8×12 Low Current Matrix Card and is organized as follows:

3.2 **CV measurements** — Outlines the test configuration and procedure for making quasistatic and high-frequency CV measurements.

3.3 **Semiconductor test matrix** — Details a semiconductor test matrix that can be used to perform a variety of different tests on semiconductors such as FETs.

3.4 **Resistivity measurements**— Covers methods to measure the resistivity of semiconductor samples using the van der Pauw method.

3.5 **Semiconductor IV characterization** — Covers the basic scheme and connections used to generate an IV curve of a bipolar or MOS transistor.

3.2 CV measurements

The Model 7174A can be used in conjunction with the Keithley Model 590 CV Analyzer, and the Keithley Model 595 Quasistatic CV Meter to perform quasistatic and high-frequency CV (capacitance vs. voltage) test on semiconductors. The resulting CV curves can be used to calculate important semiconductor parameters such as doping profile, band bending, and mobile ion concentration.

3.2.1 Stand alone system configuration

The stand alone system shown in Figure 3-1 can be used to make CV measurements without the aid of a computer. System components perform the following functions.

Model 590 CV Analyzer: Measures CV data at 100kHz and 1MHz and sends the resulting data to the plotter for graphing.

Model 595 Quasistatic CV Meter: Measures quasistatic CV data and sends the data to the plotter for graphing in real time.

Model 707A Switching Matrix: Controls the semiconductor matrix card to close and open the desired crosspoints at the proper time.

Model 7174A 8×12 Low Current Matrix Card: Switches the signa pathways to the six devices under test.

HP-GL Plotter: Plots CV and other curves directly from the Models 590 and 595.

3.2.2 Computerized system configuration

Figure 3-2 shows a computerized version of the CV matrix test system. The addition of a computer allows greater system versatility and easier instrument control. Also, analysis functions such as doping profile and ion concentration can be added to the software to expand CV analysis capabilities.

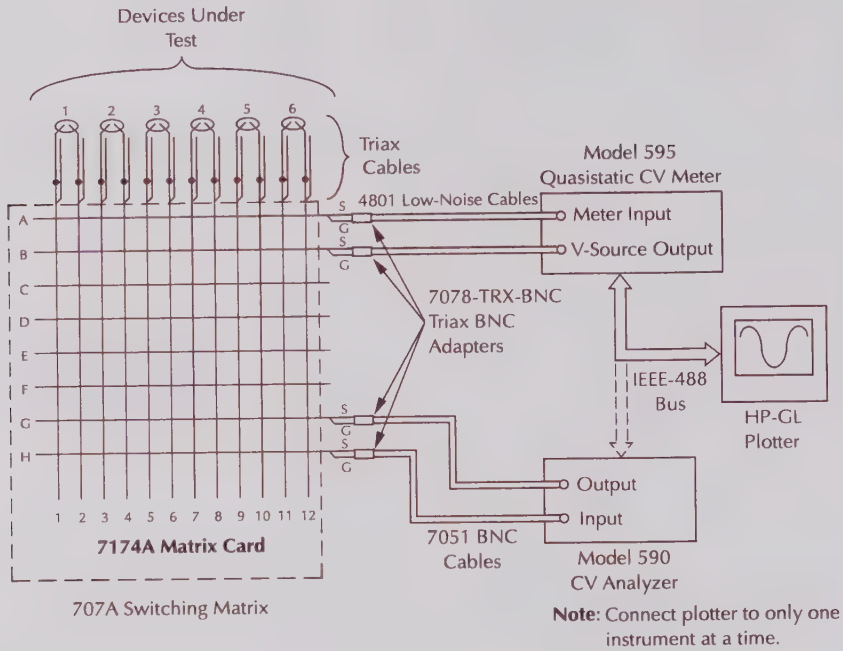

Devices Under Test
1 2 3 4 5 6
Triax Cables
Model 595 Quasistatic CV Meter
4801 Low-Noise Cables
Meter Input
V-Source Output
A B C D E F G H
7078-TRX-BNC Triax BNC Adapters
IEEE-488 Bus
HP-GL Plotter
1 2 3 4 5 6 7 8 9 10 11 12
7174A Matrix Card
Output
Input
7051 BNC Cables
Model 590 CV Analyzer
707A Switching Matrix
Note: Connect plotter to only one instrument at a time.

Figure 3-1
Stand alone CV system configuration

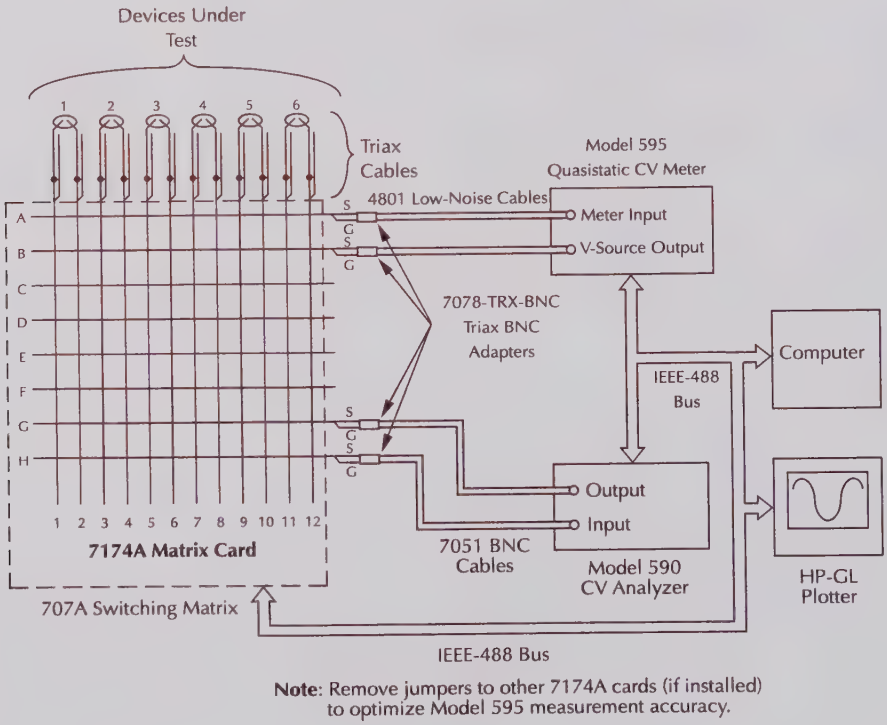

Devices Under Test
1 2 3 4 5 6
Triax Cables
Model 595 Quasistatic CV Meter
4801 Low-Noise Cables
Meter Input
V-Source Output
A B C D E F G H
7078-TRX-BNC Triax BNC Adapters
Computer
IEEE-488 Bus
1 2 3 4 5 6 7 8 9 10 11 12
7174A Matrix Card
Output
Input
7051 BNC Cables
Model 590 CV Analyzer
HP-GL Plotter
707A Switching Matrix
IEEE-488 Bus
Note: Remove jumpers to other 7174A cards (if installed) to optimize Model 595 measurement accuracy.

Figure 3-2
Computerized CV system configuration

3.2.3 Optimizing CV measurement accuracy

For accurate CV measurements, each Model 590 CV measurement pathway must be corrected using the procedure outlined in the Model 590 Instruction Manual. The pathways to each DUT must be cable corrected separately.

Also, for best quasistatic CV results, the corrected capacitance feature of the Model 595 should be used. Corrected capacitance compensates for any leakage currents present in the cables, switching matrix, or test fixture. However, care must be taken when using corrected capacitance to ensure that the device remains in equilibrium throughout the test sweep to avoid distorting the CV curves.

In order to minimize the effects of the switching network on quasistatic CV measurements, cables to the Model 595 and DUT should be kept as short as possible.

3.2.4 Basic CV test procedure

The fundamental CV test procedure is outlined below. Keep in mind that this procedure does not address many considerations and aspects of CV testing, which is fairly complex. The procedure given is for the stand alone system in Figure 3-1. Detailed instrument operating information may be found in the pertinent instruction manuals.

1. Connect the HP-GL plotter to the IEEE-488 bus connector of the Model 595 only.
2. Set up the Model 595 for the expected CV sweep.
3. Close the crosspoints necessary to connect the Model 595 to the device under test, as summarized in Table 3-1. For example, to test device #1, close A1 and B2.
4. Place the probes down on the wafer test dots.
5. Run a quasistatic sweep on the selected device and generate a CV curve.
6. Open the crosspoints that are presently closed.
7. Set up the Model 590 for the expected CV sweep.
8. Close the crosspoints necessary to connect the Model 590 to the device under test. For example, to test device #1, close G1 and H2.
9. Run a high-frequency test sweep on the device to store the CV data in the Model 590 buffer.
10. Disconnect the plotter from the Model 595 and connect it to the Model 590.
11. Generate a plot from the data in the Model 590 buffer.
12. Repeat steps 2 through 11 for the remaining devices, as required.

Table 3-1
CV test crosspoint summary

	Closed crosspoints	
Wafer #	Quasistatic (595)	High frequency (590)
1	A1, B2	G1, H2
2	A3, B4	G3, H4
3	A5, B6	G5, H6
4	A7, B8	G7, H8
5	A9, B10	G9, H10
6	A11, B12	G11, H12

3.2.5 Typical CV curves

Figure 3-3 and Figure 3-4 shows typical CV curves as generated by the Model 595 and 590 respectively. The quasistatic curve shows a fair amount of symmetry, while the high-frequency curve is highly asymmetrical. The asymmetrical nature of the high-frequency curve results from the inability of minority carries to follow the high-frequency test signal.

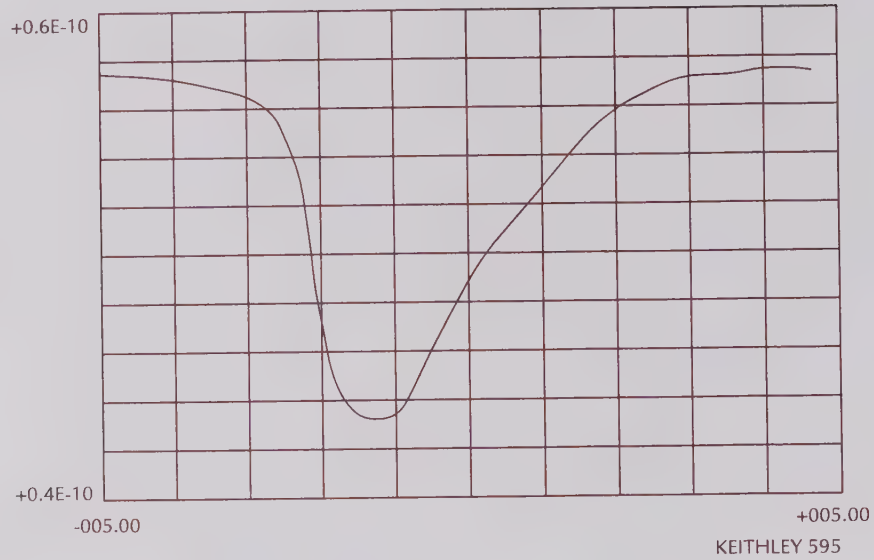


Figure 3-3
Typical quasistatic CV curve generated by Model 595

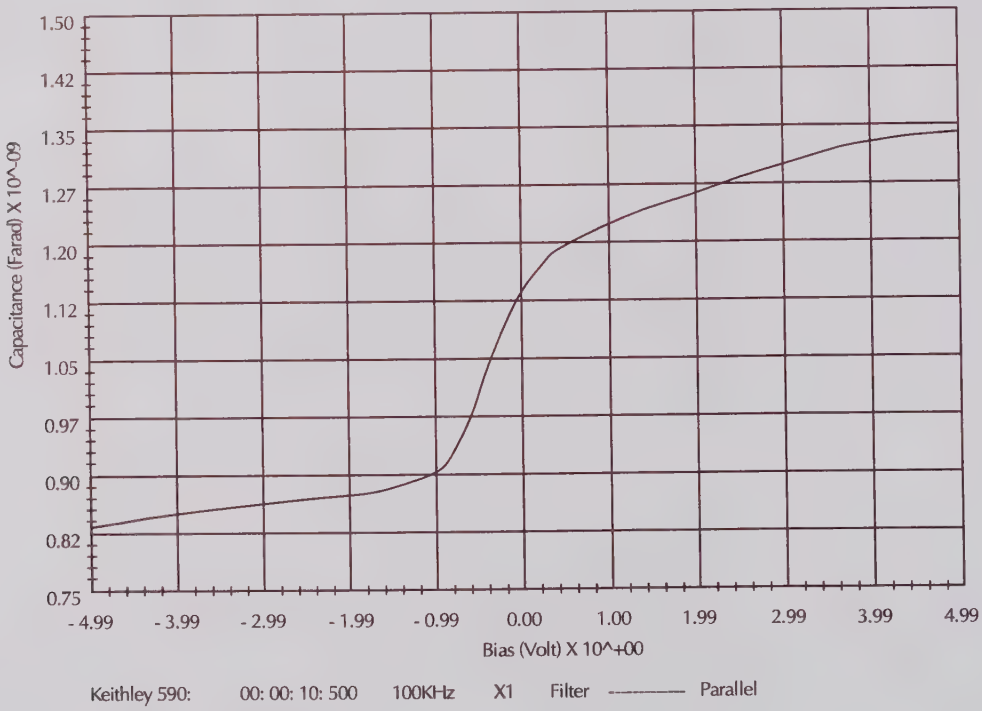


Figure 3-4
Typical high-frequency CV curve generated by Model 590

3.3 Semiconductor test matrix

Two important advantages of a matrix switching system are the ability to connect a variety of instruments to the device or devices under test, as well as the ability to connect any instrument terminal to any device test node. The following paragraphs discuss a typical semiconductor matrix test system and how to use that system to perform a typical test: common-source characteristic testing of a typical JFET.

3.3.1 System configuration

Figure 3-5 shows the configuration for a typical multipurpose semiconductor test matrix. Instruments in the system perform the following functions.

Model 617 Electrometer/Source: Measures current, and also could be used to measure voltages up to ±200VDC. The DC voltage source can supply a maximum of ±100V at currents up to 2mA.

Model 230 Voltage Source: Sources DC voltages up to ±101V at a maximum current of 100mA.

Model 590 CV Analyzer: Adds CV sweep measurement capability to the system.

Model 220 Current Source: Used to source currents up to a maximum of 101mA with a maximum compliance voltage of 105V.

Model 196 DMM: Measure DC voltages in the range of 100nV to 300V. The Model 196 could also be used to measure resistance in certain applications.

Device Under Test: A three-terminal picture for testing such devices as bipolar transistors and FETs. Additional connections could easily be added to test more complex devices, as required.

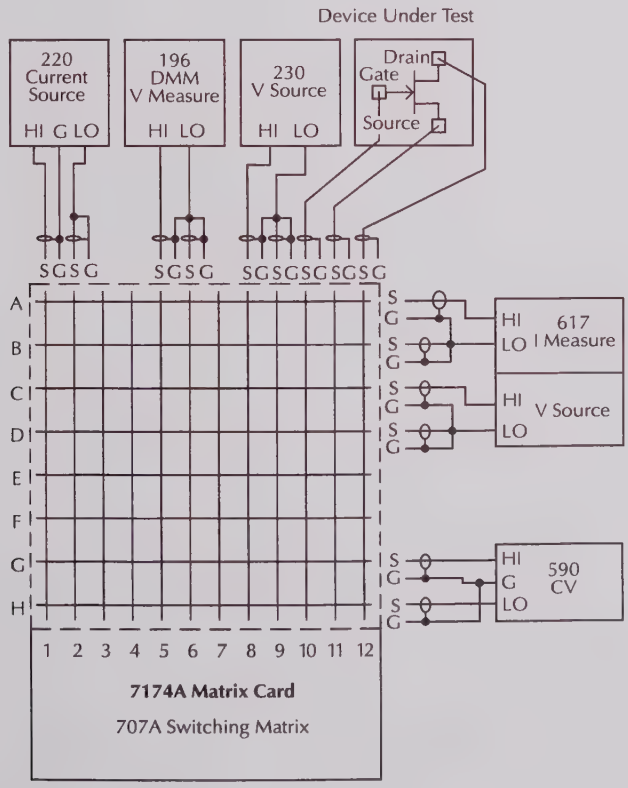


Figure 3-5
Semiconductor test matrix

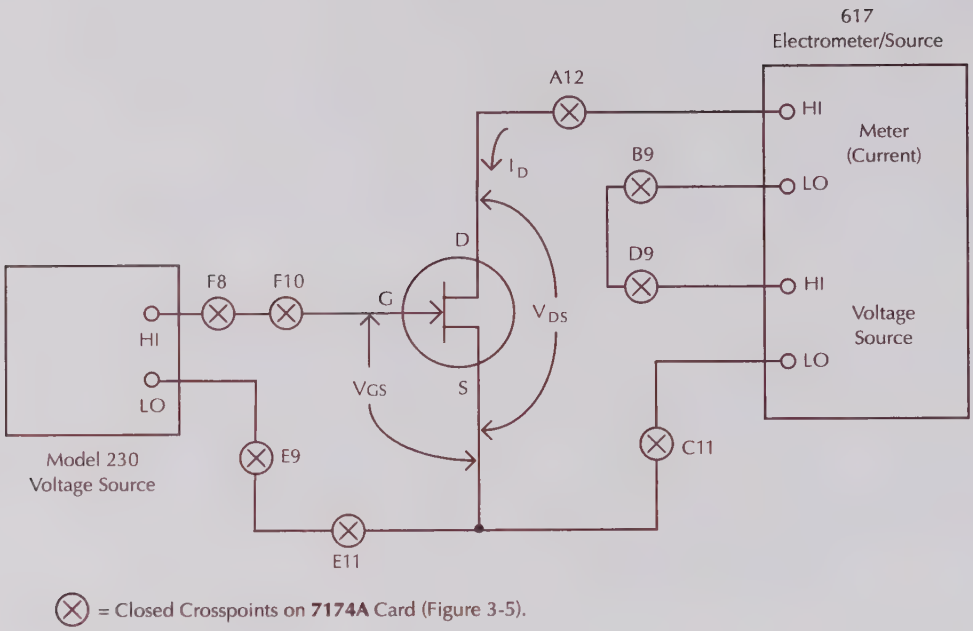


Figure 3-6
System configuration for measuring common-emitter characteristics

3.3.2 Testing common-source characteristic of FETs

The system shown in Figure 3-5 could be used to test a variety of characteristics including I_{GSS}, $I_{D[OFF]}$, $I_{G[ON]}$, I_{DSS}, and $V_{DS[OFF]}$. To demonstrate a practical use for the system, we will show how it can be used to generate common source characteristic curves of a particular JFET.

In order to generate these curves, the instrument must be connected to the JFET under test, as shown in Figure 3-6. The advantage of using the matrix is, of course, that it is a simple matter of closing specific crosspoints. The crosspoints that must be closed are also indicated on the diagram.

To run the test, V_{GS} is set to specific values, for example in increments of 0.25V. At each V_{GS} value, the drain-source voltage (V_{DS}) is stepped across the desired range, and the drain current, I_D, is measured at each value of V_{DS}. Once all data are compiled, it is a simple matter to generate the common-source IV curves, an example of which is shown in Figure 3-7. If the system is connected to a computer, the test and graphing could all be done automatically.

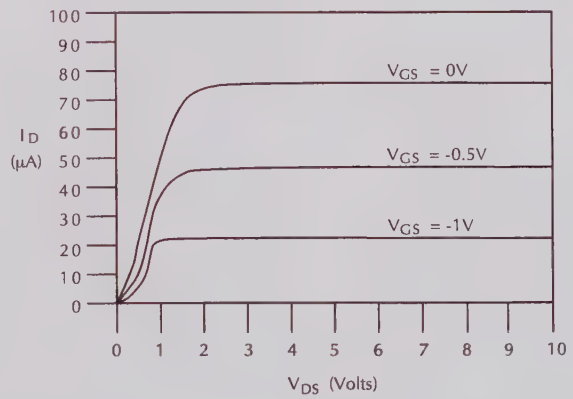


Figure 3-7
Typical common-source FET IV characteristics

3.4 Resistivity measurements

The Model 7174A 8×12 Low Current Matrix Card can be used in conjunction with a Model 220 Current Source and a Model 196 DMM to perform resistivity measurements on semiconductors. Such measurements can yield such important information as doping concentration.

3.4.1 Test configuration

Figure 3-8 shows the basic test configuration to make resistivity measurements on van der Pauw samples. The Model 220 sources current through the samples, while the Model 196 measures the voltage developed across the samples. The matrix card, of course, switches the signal paths as necessary. In order to minimize sample loading, which will reduce accuracy, the Model 196 DMM should be used only on the 300mV or 3V ranges. Also, this configuration is not recommended for resistance measurements above 1MΩ due to the accuracy-degrading effects of DMM loading.

3.4.2 Test procedure

In order to make van der Pauw resistivity measurements, four terminals of a sample of arbitrary shape are measured. A current (from the Model 220) is applied to two terminals, while the voltage is measured (by the Model 196) across the two opposite terminals, as shown in Figure 3-9. A total of eight such measurements on each sample are required, with each possible terminal and current convention. The resulting voltages are designated V1 through V8.

In order to source current into and measure the voltage across the sample, specific crosspoints must be closed. Table 3-2 summarizes the crosspoints to close for each voltage measurement on all three samples from the test configuration shown in Figure 3-8.

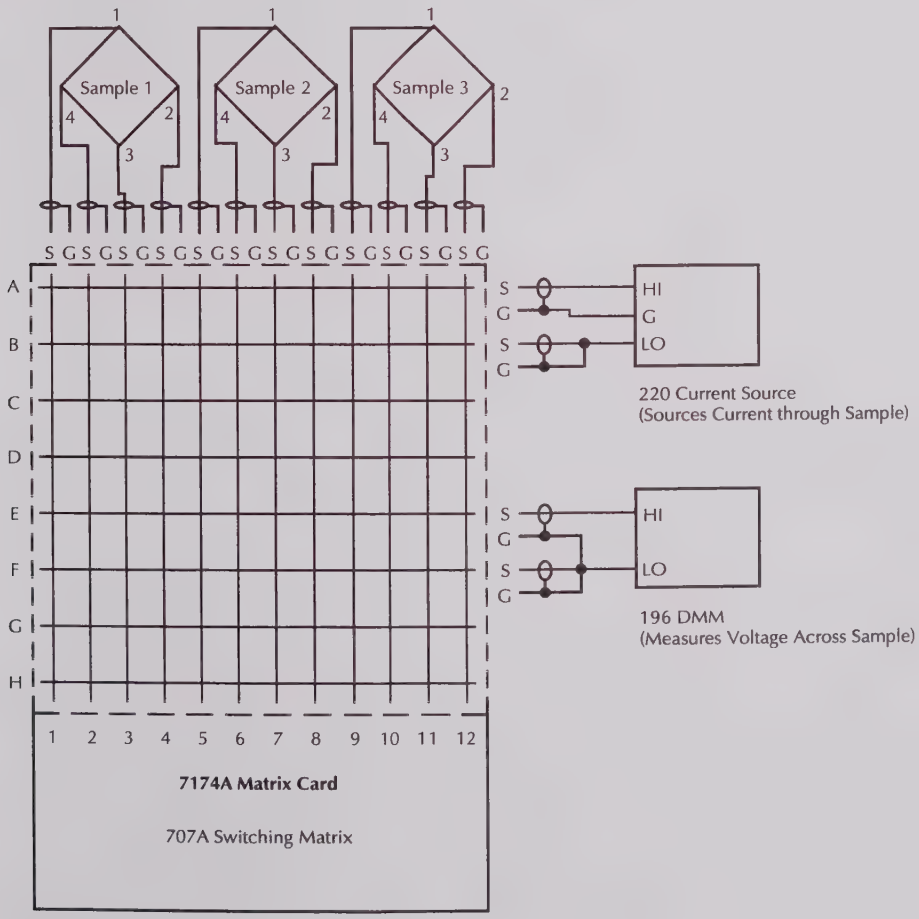


Figure 3-8
Resistivity test configuration

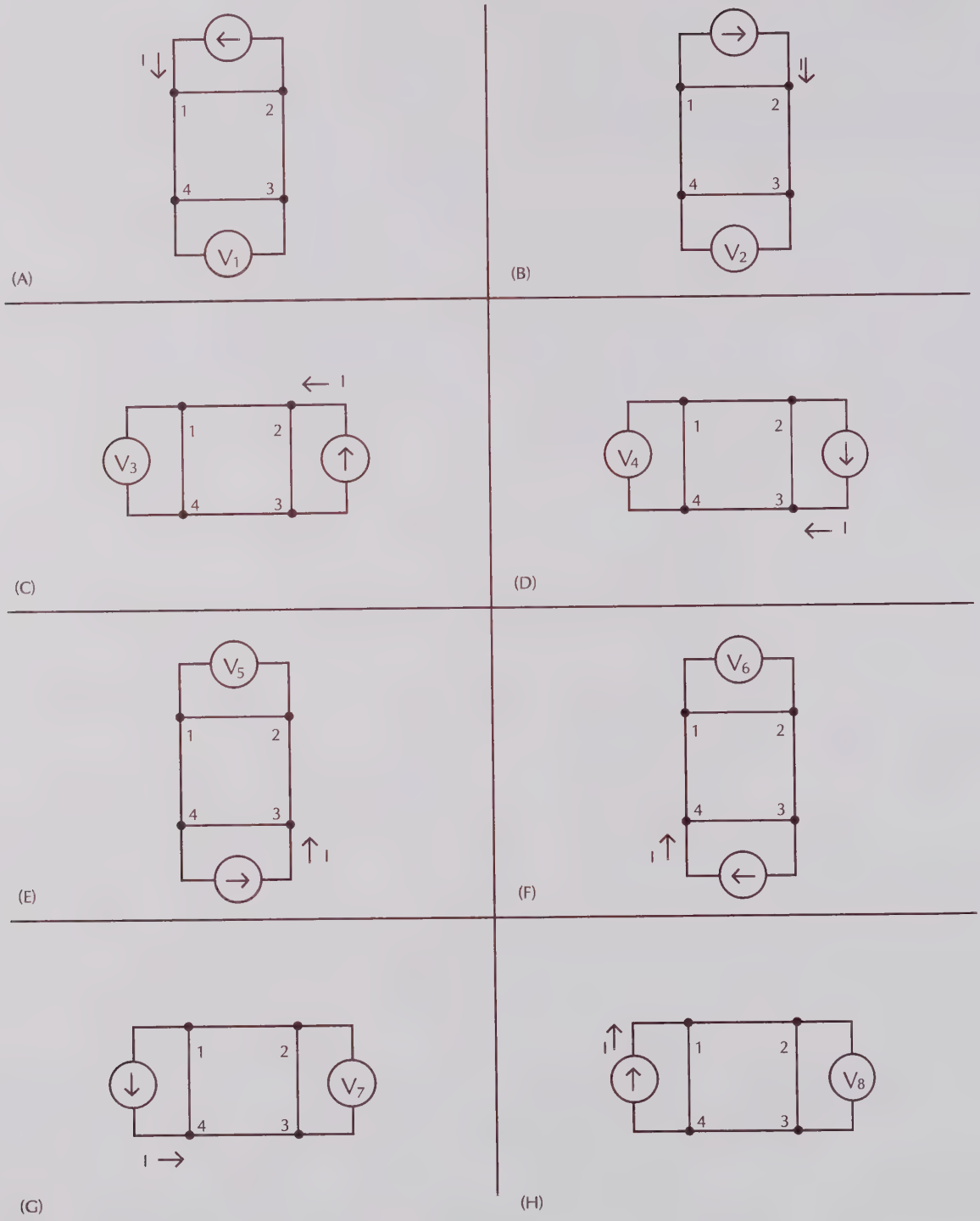


Figure 3-9
Resistivity measurement conventions

Table 3-2
Crosspoint summary for resistivity measurements

Voltage	Crosspoint closed												Current between	Voltage between
	Sample #1				Sample #2				Sample #2					
V_1	A1	B4	E3	F2	A5	B9	E7	F6	A9	B12	E11	F10	1-2	3-4
V_2	A4	B1	E3	F2	A8	B5	E7	F6	A12	B9	E11	F10	2-1	3-4
V_3	A4	B3	E2	F1	A8	B7	E6	F5	A12	B11	E10	F9	2-3	4-1
V_4	A3	B4	E2	F1	A7	B8	E6	F5	A11	B12	E10	F9	3-2	4-1
V_5	A3	B2	E1	F4	A7	B6	E5	F8	A11	B10	E9	F12	3-4	1-2
V_6	A2	B3	E1	F4	A6	B7	E5	F8	A10	B11	E9	F12	4-3	1-2
V_7	A2	B1	E4	F3	A6	B5	E8	F7	A10	B9	E12	F11	4-1	2-3
V_8	A1	B2	E4	F3	A5	B6	E8	F7	A9	B10	E12	F11	1-4	2-3

3.4.3 Resistivity calculations

Once the eight voltage measurements are known, the resistivity can be calculated. Two values of resistivity, ρ_A and ρ_B are initially computed as follows:

$$\rho_A = \frac{1.1331\, f_A t_S (V_2+V_4-V_1-V_3)}{I}$$

$$\rho_B = \frac{1.1331\, f_B t_S (V_6+V_8-V_5-V_7)}{I}$$

Where: ρ_A and ρ_B are the resistivities in Ω-cm
t_S is the sample thickness in cm
V_1 through V_8 are the voltages measured by the Model 196
I is the current through the sample in amperes
f_A and f_B are geometrical factors based on sample symmetry (f_A=f_B=1 for perfect symmetry).

Once ρ_A and ρ_B are known, the average resistivity, ρ_{AVG}, can be determined as follows:

$$\rho_{AVG} = \frac{\rho_A + \rho_B}{2}$$

3.5 Semiconductor IV characterization

A source measure unit such as the Model 236, 237, or 238 is used to test and characterize many types of devices. One of these is semiconductor devices. The following paragraphs explain the basic scheme and connections used to generate an IV curve of a bipolar or MOS transistor. Figure 3-10 shows FET devices connected in a test fixture.

3.5.1 Test configuration

Rows A and B are used to switch the Model 237 Source Measure Unit; rows C and D are used for the Model 236.

CAUTION

To prevent card damage, do not exceed the 200 volt maximum rating of the Model 7174A when switching the Model 237, which is capable of sourcing up to 1100 volts.

At the test fixture, the drain and source leads of the FETs are connected in a 4-wire sensing configuration. This connection scheme allows the Model 237 to use remote sensing to accurately apply Vds to the FETs. The Model 236 uses local sensing and is used to supply the bias to the gates of the FETs. Since the gates are low current, remote sensing is not necessary.

If more DUT pins are needed, the system is easily expanded by adding more Model 7174A matrix cards. Each additional card will add 12 columns to the system.

3.5.2 Cable connections

Source Measure Unit and test fixture connections to the matrix card are accomplished using Model 7078-TRX. These are three slot triax cables. On each Source Measure Unit, the banana jack (5-way binding post) is used to access OUTPUT LO. This connection is made using a Model 237-BAN-3 or the special cable constructed using the information in Figure 2-4. This allows OUTPUT LO to be applied to a signal pathway and independently switched. The guard pathways of the matrix cards are used exclusively to extend the driven guards of the Source Measure Units to the DUT to eliminate the effects of leakage current.

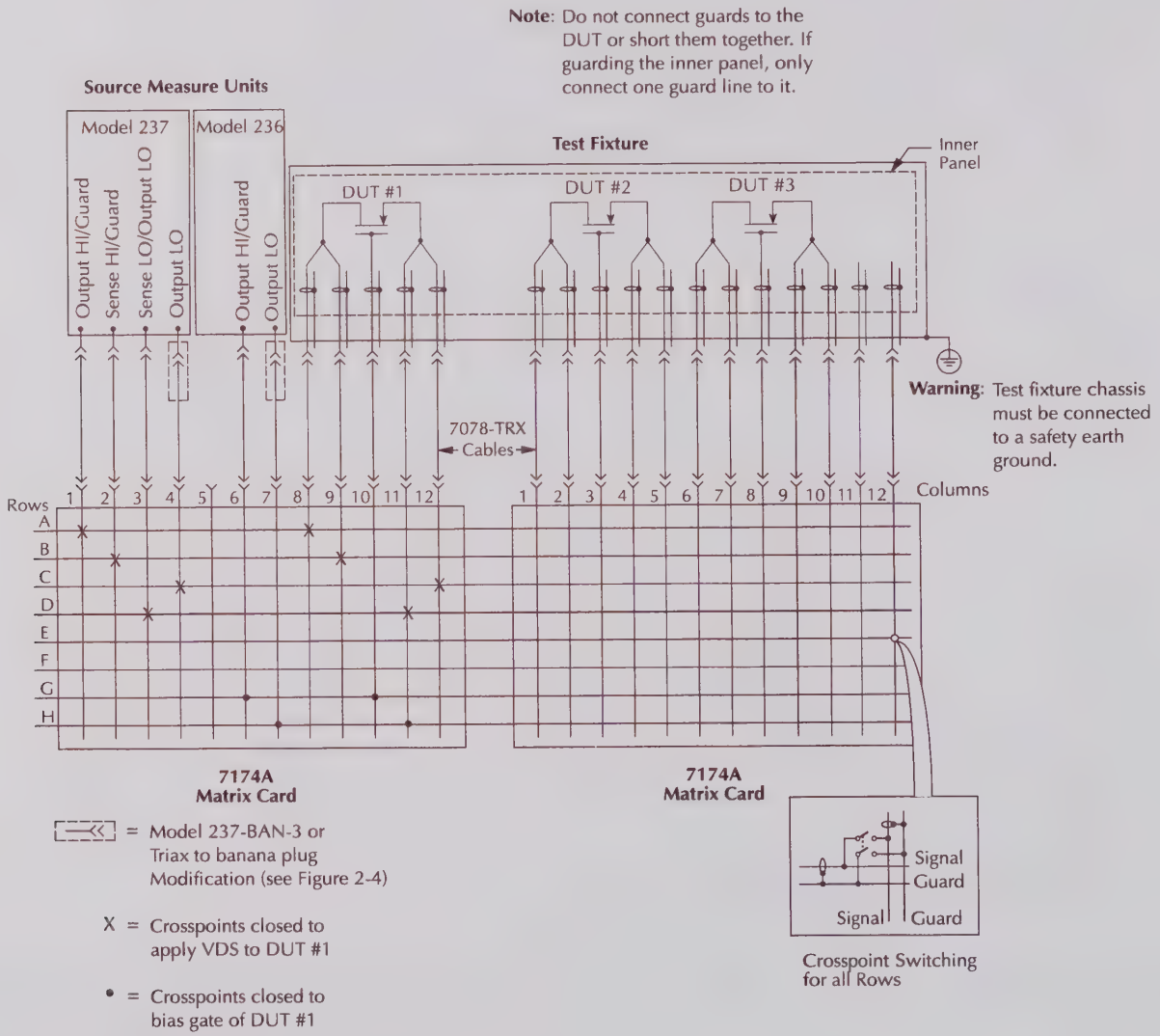


Figure 3-10
Multi unit test system using Models 236 and 237 source measure units

4

Service Information

4.1 Introduction

WARNING

The service procedures in this section are intended for use only by qualified service personnel. Do not perform these procedures unless qualified to do so. Failure to recognize and observe normal safety precautions could result in personal injury or death.

This section contains information necessary to service the Model 7174A Low Current Matrix Card and is arranged as follows:

4.2 **Handling and cleaning precautions** — Discusses handling precautions and methods to clean the card should it become contaminated.

4.3 **Principles of operation** — Briefly discusses circuit operation.

4.4 **Troubleshooting** — Presents some troubleshooting tips for the Model 7174A.

4.5 **Special handling of static-sensitive devices** — Reviews precautions necessary when handling static-sensitive devices.

4.6 **Performance verification** — Describes conditions and provides references to determine if the card is operating properly.

4.7 **Reed pack replacement** — Provides a procedure for replacing faulty reed packs.

4.2 Handling and cleaning precautions

Because of the high-impedance circuits on the Model 7174A, care should be taken when handling or servicing the card to prevent possible contamination. The following precautions should be taken when servicing the card.

1. Handle the card only by the edges and handle (do not touch the edge connectors). Do not touch any board surfaces or components not associated with the repair.
2. Do not store or operate the card in an environment where dust could settle on the circuit board. Use dry nitrogen gas to clean dust off the board if necessary.
3. When making repairs on the circuit board, use aqua core solder and OA-based (organic activated) flux. Use warm deionized water along with clean cotton swabs or a clean, soft brush to remove the flux. Take care not to spread the flux to other areas of the circuit board. Once the flux has been removed, blow dry the board with dry nitrogen gas.

NOTE

Removal of skin oils and other non-organic contaminants can be done with methanol or an HCFC.

4. After cleaning, the card should be placed in a 50°C low-humidity environment for several hours before use.

4.3 Principles of operation

The following paragraphs discuss the basic operating principles for the Model 7174A. A schematic diagram of the matrix card may be found in drawings 9174-106 (mother board) and 9174-126 (air matrix relay board) located at the end of Section 5.

4.3.1 Block diagram

Figure 4-1 shows a simplified block diagram of the Model 7174A. Key elements include the buffer (U410), ID data circuits (U406, U408, and U410), relay drivers (U101 through U113), relays (K101-K204), and the power-on safe guard (U409). The major elements are discussed below.

4.3.2 ID data circuits

At power up, the card identification data information from each card is read by the mainframe. This ID data includes such information as card ID, hardware settling time for the card, and a relay configuration table, which tells the mainframe which relays to close for a specific crosspoint. This configuration table is necessary because some cards (such as the Model 7174A) require the closing of more than one relay to close a specific crosspoint.

ID Data is contained within an on-card ROM, U406. In order to read this information, the sequence below is performed upon power up. Figure 4-2 shows the general timing of this sequence.

1. The CARDSEL line is brought low, enabling the ROM outputs. This line remains low throughout the ID data transmission sequence.
2. The CLRADDR line is pulsed clearing the address counter to zero. At this point, a ROM address of zero is selected. This pulse occurs only once.
3. The NEXTADDR line is set low. NEXTADDR going low increments the counter and enables parallel loading of the parallel-to-serial converter. NEXTADDR is kept low long enough for the counter to increment and the ROM outputs to stabilize. This sequence functions because the load input of the parallel-to-serial converter is level sensitive rather than edge sensitive. The first ROM address is location 1, not 0.
4. The CLK line clocks the parallel-to-serial converter to shift all eight data bits from the converter to the mainframe via the IDDATA line.

The process in steps 3 and 4 repeats until all the necessary ROM locations have been read. A total of 498 bytes of information are read by the mainframe during the card ID sequence.

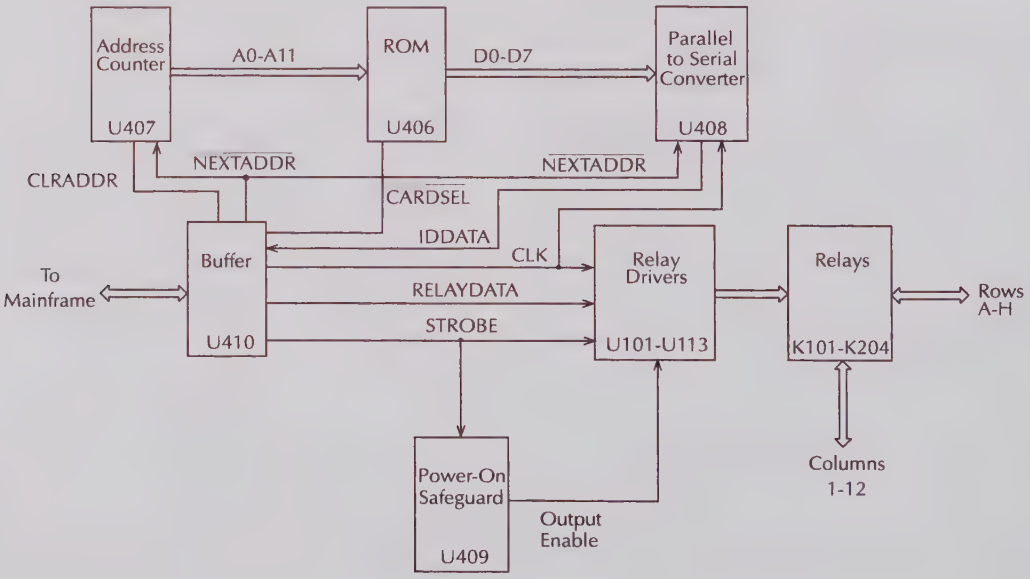
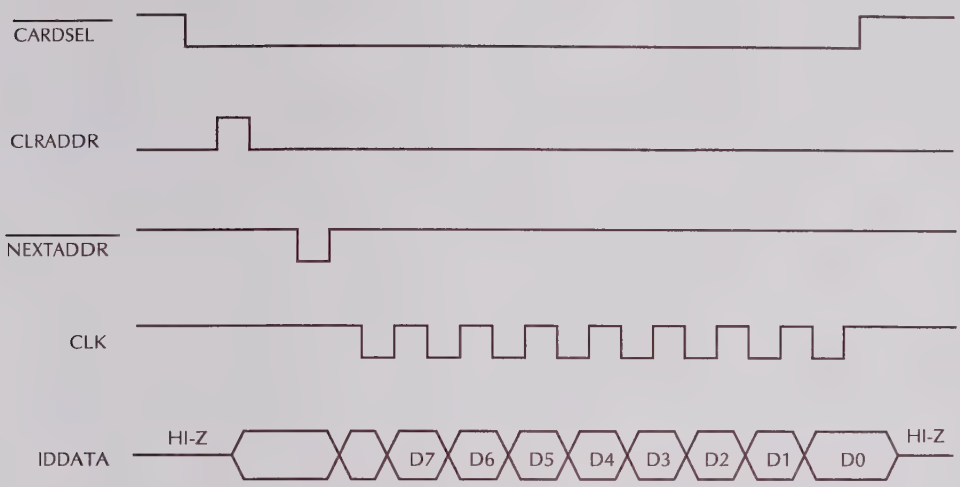


Figure 4-1
Model 7174A block diagram



Note: ID data sequence occurs on power-up only.
CLRADDR pulse occurs only once.

Figure 4-2
ID data timing

4.3.3 Relay control

The relays are controlled by serial data transmitted via the RELAY DATA line. A total of 16 bytes for each card are shifted in serial fashion into latches located in the 16 relay drivers, (U101 through U113). The serial data is fed in through the DATA lines under control of the CLK signal. As data overflows one register, it is fed out the Q's line of that register to the next IC down the chain.

Once all 16 bytes have been shifted into each card in the mainframe, the STROBE line is set high to latch the relay information into the Q outputs of the relay drivers, and the appropriate relays are energized (assuming the driver outputs are enabled, as discussed below). Logic convention is such that the corresponding relay driver output must be low to energize the associated relay, while the output is high when the relay is de-energized. For example, if the Q1 output of U113 is low, relay K197 will be energized.

4.3.4 Power-on sequence

A power-on safeguard circuit, made up of U409 and associated components, ensures that relays do not randomly energize upon power-up. The two ANG gates, U409, make up an R-S flip-flop. Initially, the Q output of the flip-flop (pin 3 of U409) is set high upon power up. Since the OEN terminals of the relay drivers (U101 through U113) are held high, their outputs are disabled, and all relays remain de-energized regardless of the relay data information preset at that time.

The first STROBE pulse that comes along (in order to load relay data) clears the R-S flip-flop, setting the OEN lines of the relay drivers low to enable their outputs. This action allows the relays to be controlled by the transmitted relay data information.

A hold-off period of approximately 470msec is included in the safeguard circuit to guard against premature enabling of the relays. The time constant of the hold-off period is determined by the relative values of R419 and C419.

4.3.5 Isolator relays

Row isolator relays are necessary in addition to the crosspoint relays in order to ensure the integrity of signal pathways. Path isolator relays include K198-K204. The necessary isolator relay is closed in addition to the selected crosspoint to complete the entire pathway. For example, if crosspoint C10 (Row C, Column 10) is closed, relays K199 and K183 would be energized.

4.4 Troubleshooting

4.4.1 Recommended equipment

Table 4-1 summarizes the recommended equipment for general troubleshooting.

Table 4-1
Recommended troubleshooting equipment

Description	Manufacturer and model	Application
5½ digit DMM	Keithley 199	Measure DC voltages
Oscilloscope	TEK 2243	View logic waveforms
Extender card	Keithley 7070	Allow circuit access

4.4.2 Gaining circuit access

In order to gain access to the test points and other circuitry on the Model 7174A, the card must be plugged into the Model 7070 Extender Card, which, in turn, must be plugged into the desired slot of the mainframe. The Model 7070 must be configured as an extender card by placing the configuration jumper in the EXTEND position. See the documentation supplied with the Model 7070 for complete details on using the card.

NOTE

Do not use the Model 7070 for performing verification tests because its presence will affect the results.

4.4.3 Troubleshooting procedure

Table 4-2 summarizes the troubleshooting procedure for the Model 7174A Low Current Matrix Card. Some of the troubleshooting steps refer to the ID data timing diagram shown in Figure 4-2. Refer to paragraph 4.3 for an overview of operating principles.

Table 4-2
Troubleshooting procedure

Step	Test point/component	Required condition	Comments
1	DGND		All voltages referenced to DGND (digital common)
2	+6V	+6VDC	Relay voltage
3	+5V	+5VDC	Logic voltage
4	NXTADR	NEXT ADDR pulses	Power up only (Fig. 4-2)
5	CLRADR	CLR ADDR pulse	Power up only (Fig. 4-2)
6	IDDATA	ID data pulses	Power up only (Fig. 4-2)
7	STRB	STROBE pulse	End of relay data sequence
8	RLDAT	Relay data (128 bits)	Present when updating relays
9	CLK	CLK pulses	Present during relay data or ID data (Fig. 4-2)
10	OE	High on power up until first STROBE sets low.	Power on safe guard
11	U101-U113 pins 10-18	Low with relay energized, high with relay de-energized.	Relay driver outputs

4.5 Special handling of static-sensitive devices

CMOS and other high-impedance devices are subject to possible static discharge damage because of the high-impedance levels involved. When handling such devices, use the precautions listed below.

NOTE

In order to prevent damage, assume that all parts are static sensitive.

1. Such devices should be transported and handled only in containers specially designed to prevent or dissipate static build-up. Typically, these devices will be received in anti-static containers made of plastic or foam. Keep these parts in their original containers until ready for installation or use.
2. Remove the devices from their protective containers only at a properly-grounded work station. Also ground yourself with an appropriate wrist strap while working with these devices.
3. Handle the devices only by the body; do not touch the pins or terminals.
4. Any printed circuit board into which the device is to be inserted must first be grounded to the bench or table.
5. Use only anti-static type de-soldering tools and grounded-tip soldering irons.

4.6 Performance verification

The following paragraphs discuss performance verification procedures for the Model 7174A, including relay testing, contact resistance, contact potential, path isolation, and leakage current.

4.6.1 Environment conditions

All verification measurements except for path isolation and offset current should be made at an ambient temperature of 21°C-25°C and a relative humidity of less than 0% R.H. Path isolation and offset current verification must be performed at an ambient temperature of 23°C and a relative humidity of less than 60% R.H. If the card has been subjected to temperatures or humidities outside of this range for even a short time, allow it to stabilize within these ranges for at least one hour before performing any tests.

4.6.2 Recommended test equipment

Table 4-3 summarizes the equipment necessary to make the performance verification tests, along with the application for each item.

Table 4-3
Recommended verification equipment

Qty.	Description	Application
1	Model 617 Electrometer	Offset current; path isolation
1	Model 196 6½ Digit DMM	Path resistance; electrometer
1	Model 707A Switching Matrix	All tests
4	Model 7078-TRX-10 triax cables*	Offset current; path resistance
2	Model 7078-TRX-3 triax cables	Path isolation; offset current; electrometer
1	Model 6172 2-slot male to 3-lug female triaxial adapter	Offset current; electrometer
3	Model 7078-TRX-T triax tee adapter	Path resistance
5	Banana plugs (part #BG-10-2*)	Path isolation and resistance
1	Model 263 Calibrator/Source	Electrometer
1	BNC to Right-angle SMB Cable (part #CA-93-1)	Electrometer
1	BNC to Dual Banana Adapter (Pomona part #1269)	Electrometer

*These items are used to construct special cables; see text and Figure 4-9.

4.6.3 Offset current verification

Recommended equipment

- Model 707A Switching Matrix
- Model 617 Electrometer
- Model 7078-TRX-3 Triax Cable
- Model 6172 2-slot male to 3-lug female triaxial adapter

Test connections

Figure 4-3 shows the test connections for offset current verification. The Model 7174A row being tested is to be connected to the Model 617 Electrometer input through the triaxial cable and the triaxial adapter. Note that the electrometer ground strap is to be removed, and the electrometer should be operated in the unguarded mode.

Procedure

NOTE

The following procedure should be performed at an ambient temperature of 23°C and at a relative humidity of less than 60%.

1. Turn on the Model 617 power and allow it to warm up for two hours before beginning the verification procedure
2. With the power off, install the Model 7174A in the desired slot of the Model 707A Switching Matrix. Remove all other cards from the instrument, and install the slot covers.
3. After the prescribed warm up period, select the amps function and the 2pA range on the Model 617. Zero correct the instrument, and then select autoranging.
4. Connect the Model 617 to row A of the Model 7174A, as shown in Figure 4-4.
5. Close crosspoint A1 by using the Model 707A front panel controls.
6. Disable zero check on the Model 617, and allow the reading to settle.
7. Verify that the offset current reading is <500fA.
8. Enable zero check on the Model 617, and open crosspoint A1.
9. Repeat steps 5 through 8 for crosspoints A2 through A12. Only one crosspoint at a time should be closed.
10. Disconnect the triax cable from row A, and connect it instead to row B.
11. Repeat steps 5 through 8 for crosspoints B1 through B12. Only one crosspoint at a time should be closed.
12. Connect the triax cable to each succeeding row and repeat steps 5 through 8 for each of the row's crosspoints.

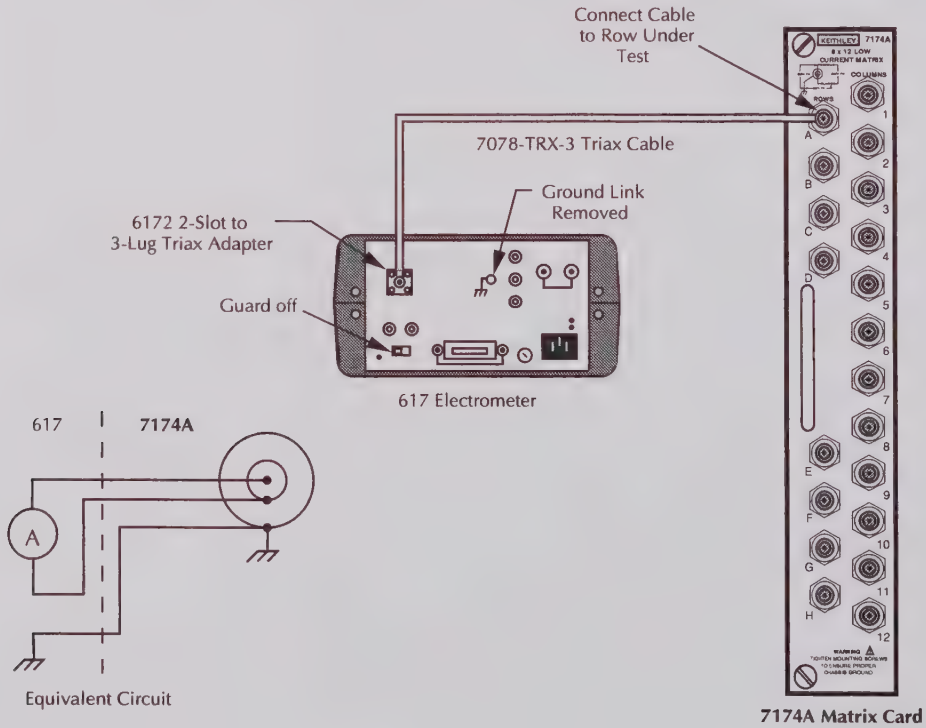


Figure 4-3
Offset verification test connections

4.6.4 Path isolation verification

The procedure for verifying path isolation is discussed below. Should the card fail any of the tests, clean it using the procedures outlined in paragraph 4.2.

Recommended equipment

- Model 707A Switching Matrix
- Model 617 Electrometer
- Model 7078-TRX-3 Triax Cable
- Unterminated 3-slot triaxial cable (cut connector off 7078-TRX-3)
- Banana plug (Keithley part #BG-10-2)
- #16-18AWG insulated stranded wire (6 in. length)

Test connections

Figure 4-4 shows the test connections for the path isolation tests. One row being tested is to be connected to the Model 617 Electrometer input through a Model 6172 2-slot female to 3-lug male triaxial adapter. The other row is to be connected to the voltage source HI terminal using a specially prepared 3-slot triax-to-banana plug cable, the construction of which is shown in Figure 4-5. Note that both the inner shield and the center conductor are to be connected to the banana plug as shown.

COM and LO terminal of the electrometer voltage source must be connected together as shown. Also, the ground link between COM and chassis must be removed, and the Model 617 guard must be turned off for current measurements.

Procedure

WARNING

Hazardous voltage from the electrometer voltage source will be used in the following steps. Take care not to contact live circuits, which could cause personal injury or death.

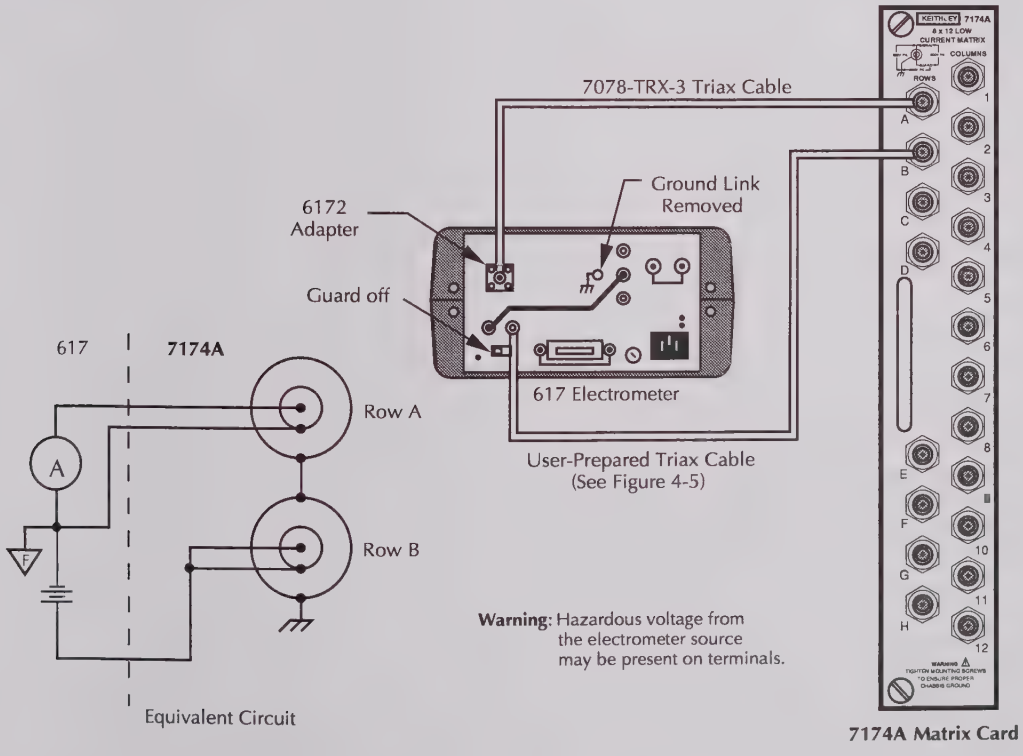
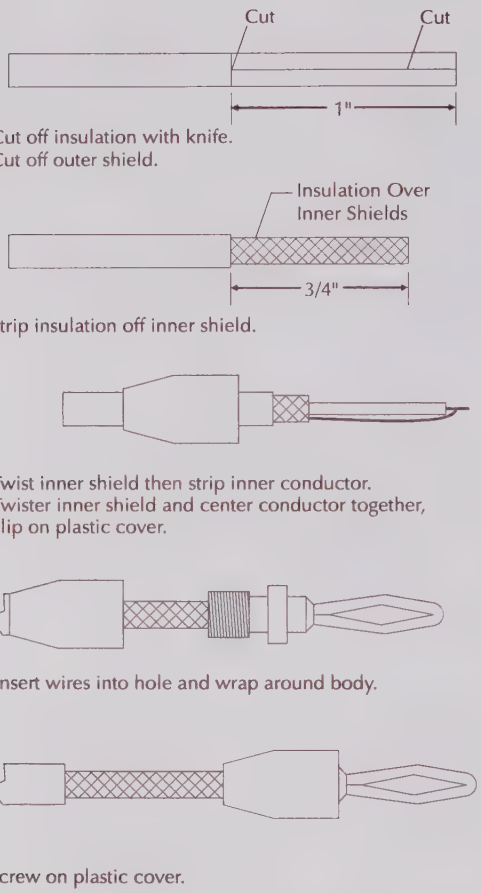


Figure 4-4
Connections for path isolation verification



(A) Cut off insulation with knife.
Cut off outer shield.

(B) Strip insulation off inner shield.

(C) Twist inner shield then strip inner conductor.
Twister inner shield and center conductor together,
slip on plastic cover.

(D) Insert wires into hole and wrap around body.

(E) Screw on plastic cover.

Figure 4-5
Triaxial cable preparation

NOTE

The following procedure must be performed at an ambient temperature of 23°C and at a relative humidity of less than 60%.

1. Turn on the Model 617 and allow it to warm up for two hours for rated accuracy.
2. With the mainframe power turned off, plug the Model 7174A into slot 1 of the mainframe. Remove all other cards from the mainframe, and install the slot covers.
3. After the prescribed warm up period, select the Model 617 amps function, and enable zero check. Select the 2pA range, and zero correct the instrument.
4. Connect the Model 617 to rows A and B of the matrix card, as shown in Figure 4-4.
5. Program the Model 617 voltage source for a value of +100V, but do not yet turn on the voltage source output.
6. Close crosspoints A1 and B2 by using the switching matrix front panel controls.
7. With the Model 617 in amps, enable suppress after the reading has settled.
8. Turn on the Model 617 voltage source output, and enable the V/I ohms function on the electrometer.
9. After the reading has settled, verify that the resistance is >67TΩ ($6.7\times10^{13}\Omega$).
10. Turn off the voltage source, and enable zero check. Disable suppress, and select the amps function on the electrometer.
11. Open crosspoints A1 and B2, and close crosspoints A3 and B4.
12. Repeat steps 7 through 11 for A3 and B4.
13. Repeat steps 7 through 12 for crosspoint pairs A5 and B6, A7 and B8, A9 and B10, and A11 and B12.
14. Disconnect the electrometer from rows A and B, and connect it instead to rows C and D.
15. Repeat steps 7 through 13 for rows C and D. The path isolation for these rows should be 67TΩ ($6.7\times10^{3}\Omega$).
16. Repeat steps 7 through 14 for row pairs E and F, and G and H. For each row pair, step through the crosspoint pairs 1 and 2, 3 and 4, 5 and 6, 7 and 8, 9 and 10, and 11 and 12. The complete procedure outlined in steps 7 through 11 should be repeated for each crosspoint pair. Each resistance measurement for rows E through H should be 67TΩ ($6.7\times10^{13}\Omega$).

4.6.5 Path resistance verification

The following paragraphs discuss the equipment, connections, and procedure to check path resistance. Should a particular pathway fail the resistance test, the relay (or relays) for that particular crosspoint is probably defective. See the schematic diagram at the end of Section 5 to determine which relay is defective.

NOTE

The following procedure verifies the resistance of the HI signal path. To verify the resistance of the GUARD path, modify the cable of Figure 4-5 to connect the inner shield to the banana plug and have no connection to the triax center conductor.

Recommended equipment

- Model 196 DMM
- 7078-TRX-T triax tee adapters (3)
- 237-BAN-3 triax to banana cables (4)

Connections

Figure 4-6 shows the connections for the path resistance tests. The Model 196 is to be connected to the row and column jacks using Model 237-BAN-3 triax/banana cables. These cables differ from the one in Figure 4-5 in that the inner shield and center conductor are not connected together.

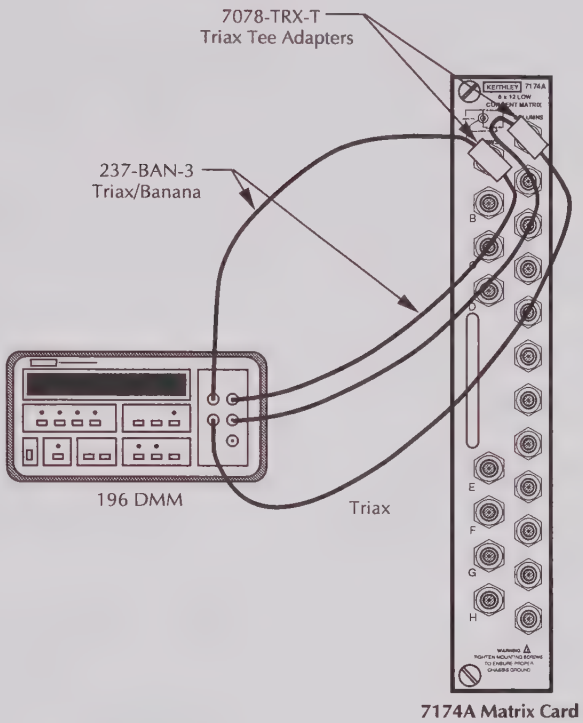


Figure 4-6
Connections for path resistance verification

Procedure

1. Turn on the Model 196 DMM and allow it to warm up for at least one hour before beginning the test.
2. With the power off, install the Model 7174A card in slot 1 of the mainframe.
3. Connect the four triaxial cables to the Model 196 and the two triax tee adapters (Figure 4-6), but do not yet connect the adapters to the Model 7174A.
4. Temporarily connect the two triax tee connectors together using a third triax tee adapter, as shown in Figure 4-7.
5. Select the ohms function, 300Ω range, and 6½ digit resolution on the Model 196.
6. After the reading settles, enable zero on the Model 196 DMM. Leave zero enabled for the remainder of the tests.
7. Disconnect the two triax tee adapters from the shorting adapter, and connect the two adapters with the cable to the row A and column 1 connectors on the Model 7174A (see Figure 4-6).
8. Close crosspoint A1, and allow the reading to settle.
9. Verify that the resistance reading is <1.5Ω.
10. Open the crosspoint, and disconnect the triax adapter from column 1. Connect the adapter to column 2.
11. Repeat steps 8 through 10 for columns 2 through 12. In each case, the column adapter must be connected to the column under test, and the crosspoint must be closed.
12. Disconnect the row adapter from row A, and connect it instead to row B.
13. Repeat steps 8 through 10 for row B. The crosspoints of interest here are B1 through B12. Also, the row adapter must be connected to the row being tested.
14. Repeat steps 8 through 13 for rows C through H. In each case, the crosspoint to close is the one corresponding to the row and column connections at that time. In all cases, the measured resistance should be <1.5Ω.

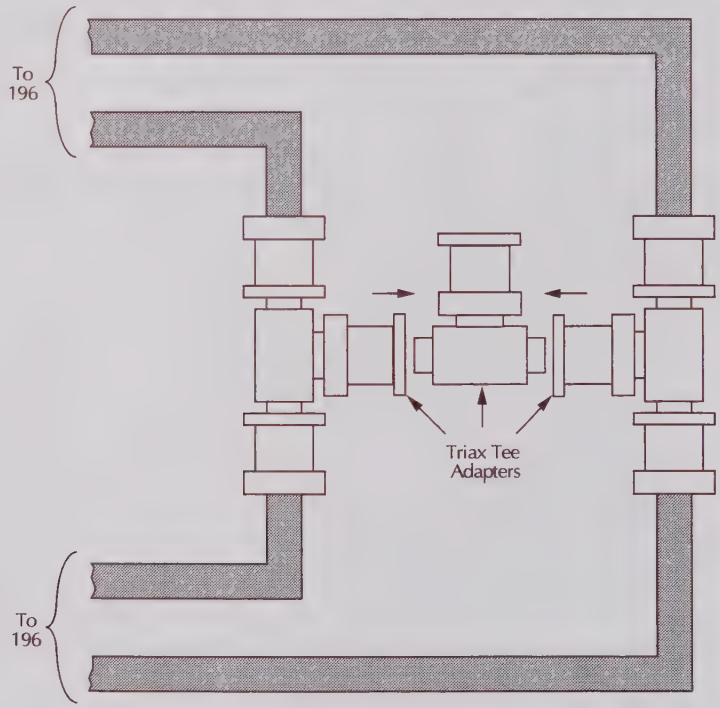


Figure 4-7
Shorting measurement paths using triax tee adapter

4.7 Reed pack replacement

If after performing troubleshooting or verification, a reed switch is thought to be faulty, it should be replaced. Note that reeds can only be replaced as a pack of three. The part number for a reed pack is RL-179. A reed pack maintenance kit, part number 9174-MK is also suggested.

Cross point relay

Use the following procedure and Figure 4-8 to replace cross point relay reed packs.

NOTE

Repairs should only be done from the component side of the board.

1. Remove the card and place on an anti-static surface.
2. Put on the gloves that came in the maintenance kit.
3. Carefully pry off the cover of the guard enclosure of the crossbar that includes the suspect reed. Take care not to break the wire that connects the cover to the front panel.
4. Carefully pry off the cross point interconnect board. Take care not to break the wires that connect the interconnect board to the front panel.
5. Using clean needle-noise pliers, carefully remove the reed pack in question.
6. Inspect the relay coil. If there is any debris or contamination, clean with methanol and blow out with dry nitrogen.

NOTE

When inserting reed pack, make sure long leads are inserted into relay coil (bobbin).

7. Using the reed pack insertion tool from the maintenance kit, install the new reed pack into bobbin making sure the long leads align with the holes at the base of the relay coil (bobbin).
8. Reinstall any reed packs that may have been removed when the cross point interconnect board was removed.
9. Reinstall the cross point interconnect board. Be sure that it is properly seated.
10. Reinstall the guard enclosure cover.
11. Allow the card to stabilize for one hour.
12. Retest the card to verify operation and specifications.

Isolator relay

Use the following procedure and Figure 4-9 to replace isolator relay reed packs.

NOTE

Repairs should only be done from the component side of the board.

1. Remove the card and place on an anti-static surface.
2. Put on the gloves that came in the maintenance kit.
3. Carefully pry off the cover of the guard enclosure. Take care not to break wires connecting the relay to the pathway interconnect board.
4. Using clean needle nose pliers, carefully disconnect the three wires that attach to the reed pack, taking note of the locations for each.
5. Remove the reed pack in question.
6. Inspect the reed pack socket. If there is any debris or contamination, clean with methanol and blow out with dry nitrogen.

NOTE

When inserting reed pack, make sure long leads are inserted into relay coil (bobbin).

7. Using the reed pack insertion tool from the maintenance kit, install the new reed pack into bobbin making sure the long leads align with the holes at the base of the relay coil (bobbin).
8. Reconnect the wires to the top of the reed pack.
9. Reinstall the guard enclosure cover.
10. Allow the card to stabilize for one hour.
11. Retest the card to verify operations and specifications.

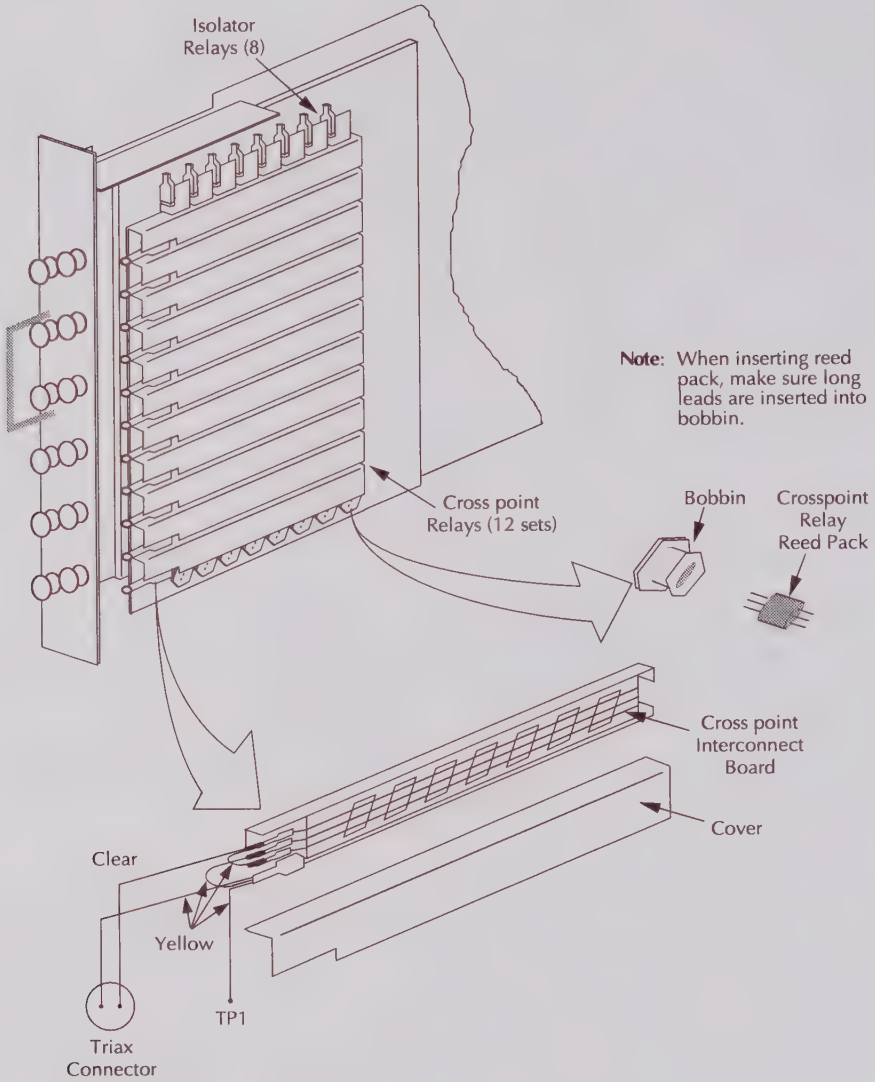


Figure 4-8
Cross point relays

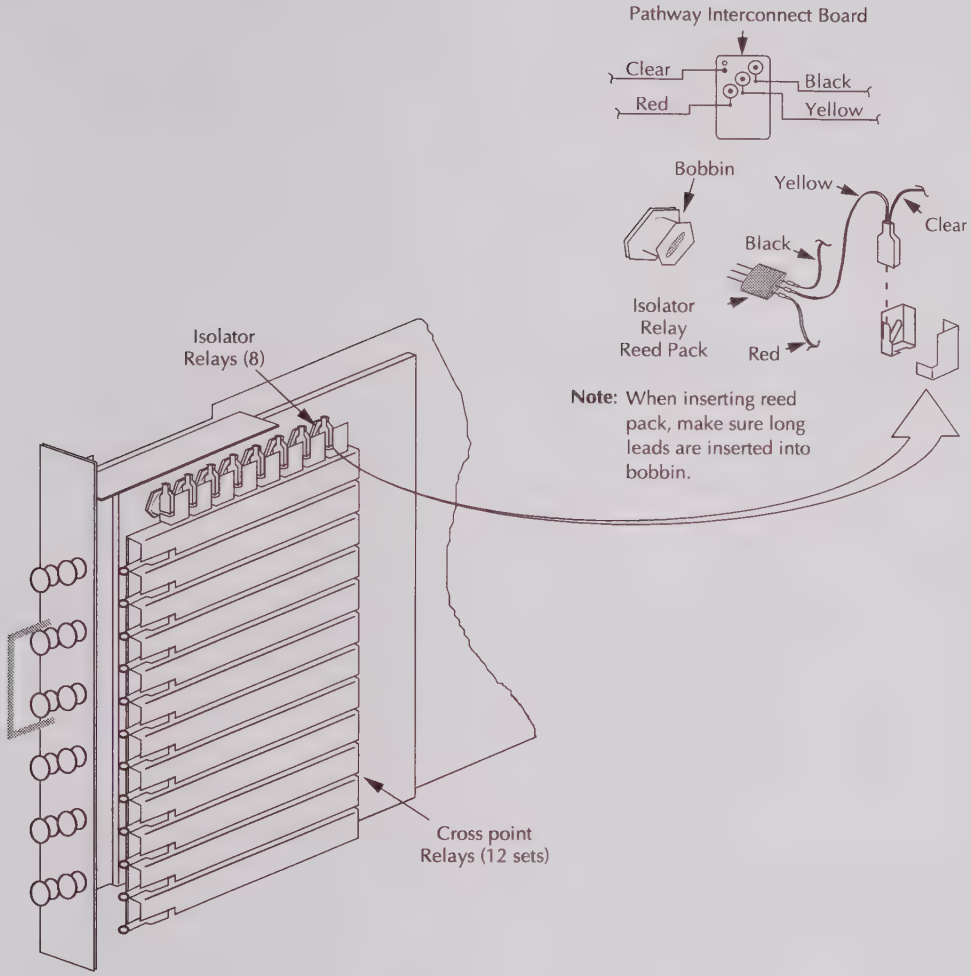


Figure 4-9
Isolator relays

5
Replaceable Parts

5.1 Introduction

This section contains a list of replaceable electrical and mechanical parts for the Model 7174A, as well as a component layout drawing and schematic diagram of the matrix card.

5.2 Parts list

Electrical parts are listed in order of circuit designation in Table 5-1. Table 5-2 summarizes mechanical parts.

5.3 Ordering information

To place an order, or to obtain information about replacement parts, contact your Keithley representative or the factory (see the front of this manual for addresses). When ordering parts, be sure to include the following information:

1. Matrix card model number 7174A.
2. Card serial number
3. Part description
4. Circuit designation, if applicable
5. Keithley part number

5.4 Factory service

If the matrix card is to be returned to Keithley Instruments for repair, perform the following:

1. Call the Repair Department at 1-800-552-1115 for a Return Authorization (RMA) number.
2. Complete the service form located at the back of this manual, and include it with the unit.
3. Carefully pack the card in the original packing carton or the equivalent.
4. Write ATTENTION REPAIR DEPARTMENT and the RMA number on the shipping label. Note that it is not necessary to return the matrix mainframe with the card.

5.5 Component layout and schematic diagram

Mother board

- Component layout — 9174-100
- Schematic — 9174-106

Relay board

- Component layout — 9174-120
- Schematic — 9174-126 (sheets 1 and 4 only)

Pathway interconnect board

- Component layout — 7174-160
- Schematic — 7174-166

Table 5-1
Model 7174A electrical parts list

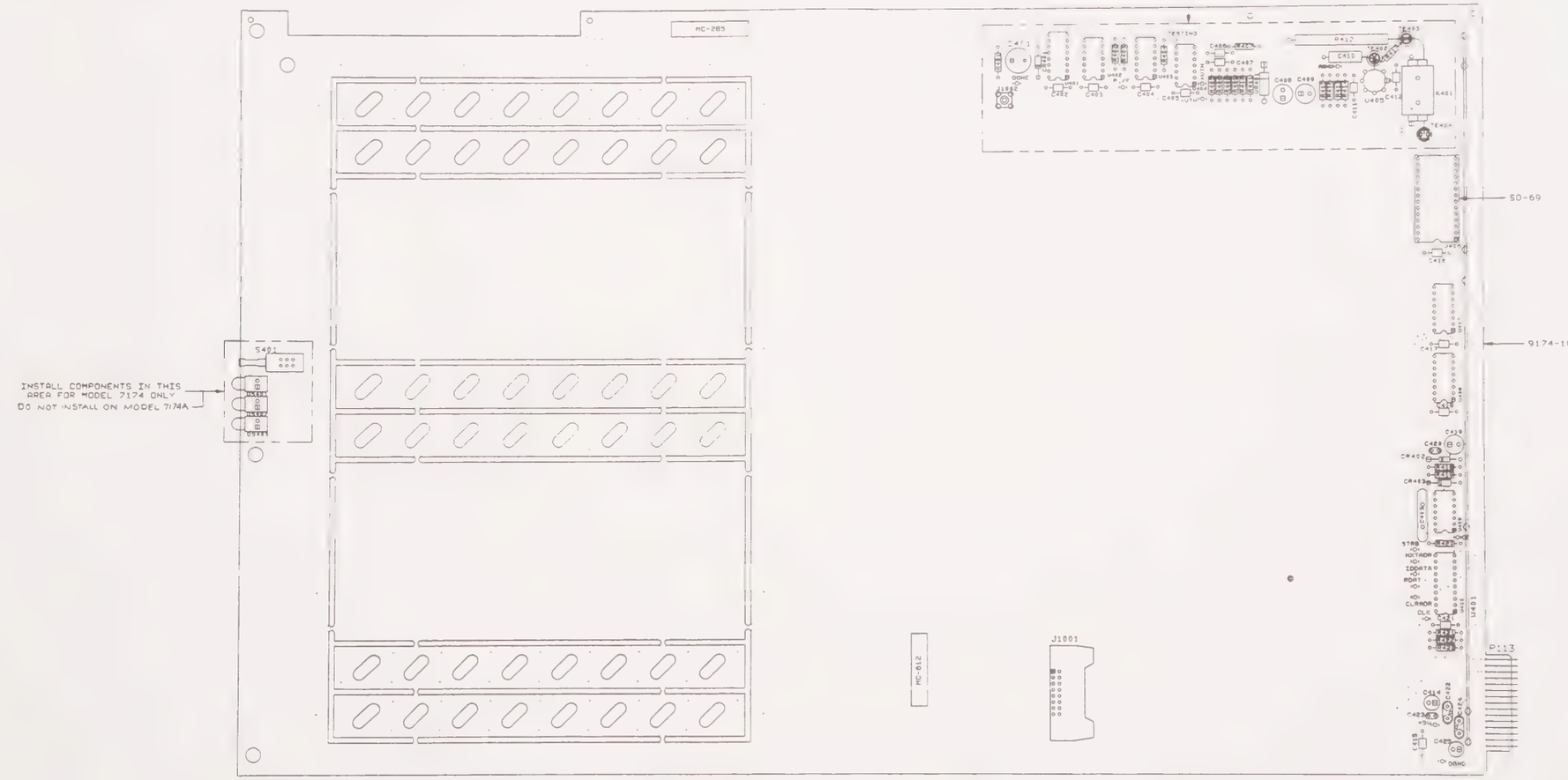
Circuit Desig.	Description	Keithley Part No.
C101-113	CAP, .1µF, 20%, 50V, CERAMIC	C-365-.1
C415-418, 421	CAP, .1µF, 20%, 50V, CERAMIC	C-365-.1
C413	CAP, .01µF, 10%, 1000V, CERAMIC	C-64-.01
C414, 425	CAP, 10µF, -20+100%, 25V, ALUM ELEC	C-314-10
C419	CAP, 47µF, 10%, 16V, ALUM ELEC	C-321-47
C420, 423	CAP, .01µF, 20%, 50V, CERAMIC	C-237-.01
C422, 424	CAP, 270pF, 20%, 100V, CERAMIC/FERRITE	C-386-270P
CR403	DIODE, SILICON, IN4148 (DO-35)	RF-28
CR402	DIODE, SCHOTTKY, IN5711	RF-69
J1001	CONNECTOR	CS-598
J1001-1003	CONNECTOR, MALE	CS-389-2
K101-204	REED PACK 3 FORM, DUAL GUARDED	RL-179
K101-204	RELAY, AIR MATRIX BOBBIN	RL-177
R101-128	RES, 22M, 5%, 1/4W, COMPOSITION OR FILM	R-76-22M
R417, 418	RES, 10K, 5%, 1/4W, COMPOSITION OR FILM	R-76-10K
R419	RES, 47K, 5%, 1/4W, COMPOSITION OR FILM	R-76-47K
R420	RES, 200, 5%, 1/4W, COMPOSITION OR FILM	R-76-200
R421	RES, 680, 5%, 1/4W, COMPOSITION OR FILM	R-76-680
R422	RES, 120K, 5%, 1/4W, COMPOSITION OR FILM	R-76-120K
R423	RES, 11K, 5%, 1/4W, COMPOSITION OR FILM	R-76-11K
U101-113	IC, 8-BIT SERIAL-IN LATCH DRIVER, 5841A	IC-536
U406	PROGRAM	7174-800A02*
U407	IC, 12 STAGE BINARY COUNTER, 74HCT4040	IC-545
U408	IC, 8-BIT PARALLEL TO SERIAL, 74HCT165	IC-548
U409	IC, QUAD 2 INPUT NAND, 74HCT00	IC-399
U410	IC, OCTAL BUFFER/LINE DRIVER, 74HC244	IC-489
W401	STIFFENER, BOARD	J-16

*Order present firmware revision level.

Table 5-2
Model 7174A mechanical parts list

Description	Keithley Part No.
#4-40X1/4 PHILLIPS PAN HD SEMS SCREW (9174-162 BOARD TO BRACKETS)	4-40X1/4PPHSEM
#6-32X3/8LG. PHIL FLAT HD SCR (HANDLE MTG)	6-32X3/8PFH
#6-32X5/16PHIL PAN HED SEMS SCR (R. PANEL TO MB; BRKT TO BD)	6-32X5/16PPHSEM
#6-32 PEM NUT	FA-135
8 POS INTERCONNECT	9174-315B
13 POS INTERCONNECT	9174-314B
BRACKET	9174-307A
BRACKET	9174-308A
CABLE	CA-121A
CABLE ASSEMBLY, 16 CONDUCTOR	CA-27-13C
CAP, PROTECTIVE	CAP-30-1
CONN, TEST POINT (DONE,IDDATA,NXTADR,OR,P,/F,RDAT,STRB)	CS-553
CONN, TEST POINT (+5V, +VTH, -VTH,AGND,CLK,CLRADR,DGND)	CS-553
CONNECTOR (ON SC-120-4)	CS-236
FASTENER	FA-257-1
FEMALE, BULKHEAD MOUNT RECEPTACLE	CS-824
GROUND CLIP	9174-313A
GUARD TUBE, BASE	9174-301A
GUARD TUBE, LID	9174-302A
GUARD TUBE, BASE	9174-303A
GUARD TUBE, LID	9174-304A
GUARD TUBE, BASE	9174-305A
GUARD TUBE, LID	9174-306A
HANDLE	HH-33-1
LOCKNUT (REL BD TO FASTENERS, BRKT TO BD)	FA-226-1
LUG (ON SC-83, SC-120-4)	LU-108-2
LUG (ON SC-120-4)	LU-108-2
REAR PANEL ASSEMBLY	7174A-301A
SOCKET (SOLDERED ON SC-83 AND SC-120-4)	SO-144
SOCKET, I.C. 28 PIN (FOR U406)	SO-69
SPACER, LID	9174-316A
STRIP TERMINAL (FOR SC-111)	CS-812
SUPPORT	9174-309A
TEFLON TWISTED PAIR SHLD	SC-83
TERMINAL, BIFURCATED (TEFLON)	TE-119
TEST PIN	TE-108
TRIAX CONNECTOR (FOR SC-111	CS-827
WIRE, SINGLE CONDUCTOR	SC-120-4

LTR	ECO NO	REVISION	ENG	DATE
A	940725	RELEASED	SZ	2-25-94
B	16785	CHG D ARTWORK FROM REV A TO B.		
B1	20589	ADDED DO NOT INSTALL ON MODEL 7174A		



NOTE:
FOR COMPONENT INFORMATION REFER TO 9174-WSM, 9174-WSMI, AND 7174 PRODUCT STRUCTURE.

MODEL	NEXT ASSEMBLY	QTY USED ON
7174A		1
9174-BDC		1
9174-BDM		1

DO NOT SCALE THIS DRAWING	DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 6/9/94	SCALE 1:1	TITLE COMPONENT LAYOUT, MOTHER BOARD
KEITHLEY INSTRUMENTS INC. CLEVELAND, OHIO 44139	XX=±.015 ANG =±1°	DRN AJS	ENG APPR. WK	
	XXX=±.005 FRAC =±1/64	MATERIAL N/A	D	NO. 9174-100
	SURFACE MAX 63	FINISH N/A		

INSTALL PARTS FOR
MODEL 7174 ONLY

* DO NOT INSTALL FOR 7174A

SWITCH SHOWN IN
NORMAL POSITION

OFFSET CURRENT
1mV/10fA
SMB CONNECTOR

SPARES

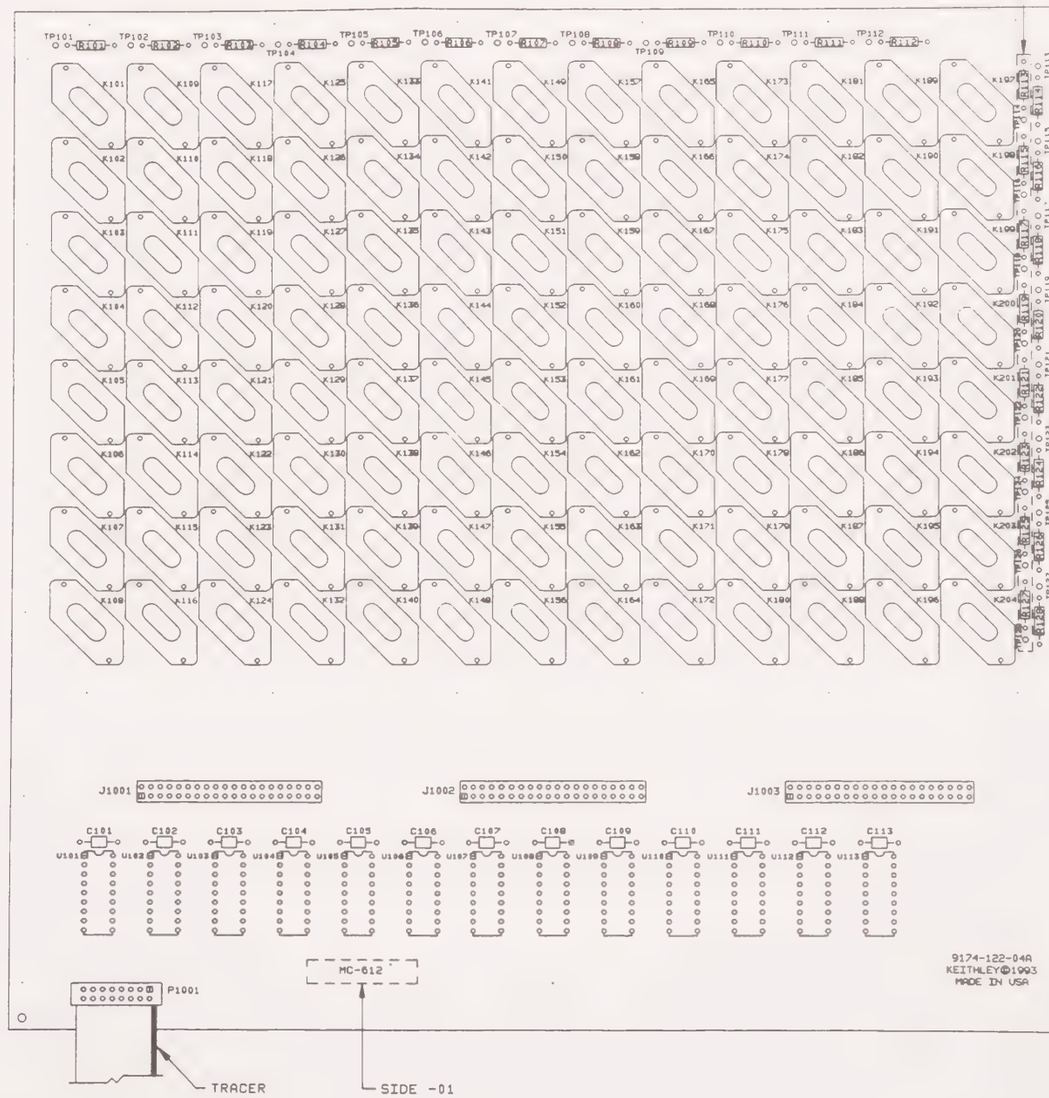
KEITHLEY	KEITHLEY INSTRUMENTS INC CLEVELAND, OHIO 44139		
TITLE: SCHEMATIC, MOTHER BOARD			
SIZE: D	MODEL: 9174-HSM	NO: 9174-106	ECO: 20589
REV: B1	DRAWN: AJS	APPROVED: WK	DATE: 12/31/97

ORIGINAL IF RED

NO. 9174-120

LTR.	ECO NO.	REVISION	ENG.	DATE
A	940419	RELEASED		9-19-94

INSTALL RESISTORS IN THIS ROW
FOR MODELS 9174-HSMI & 7174 ONLY



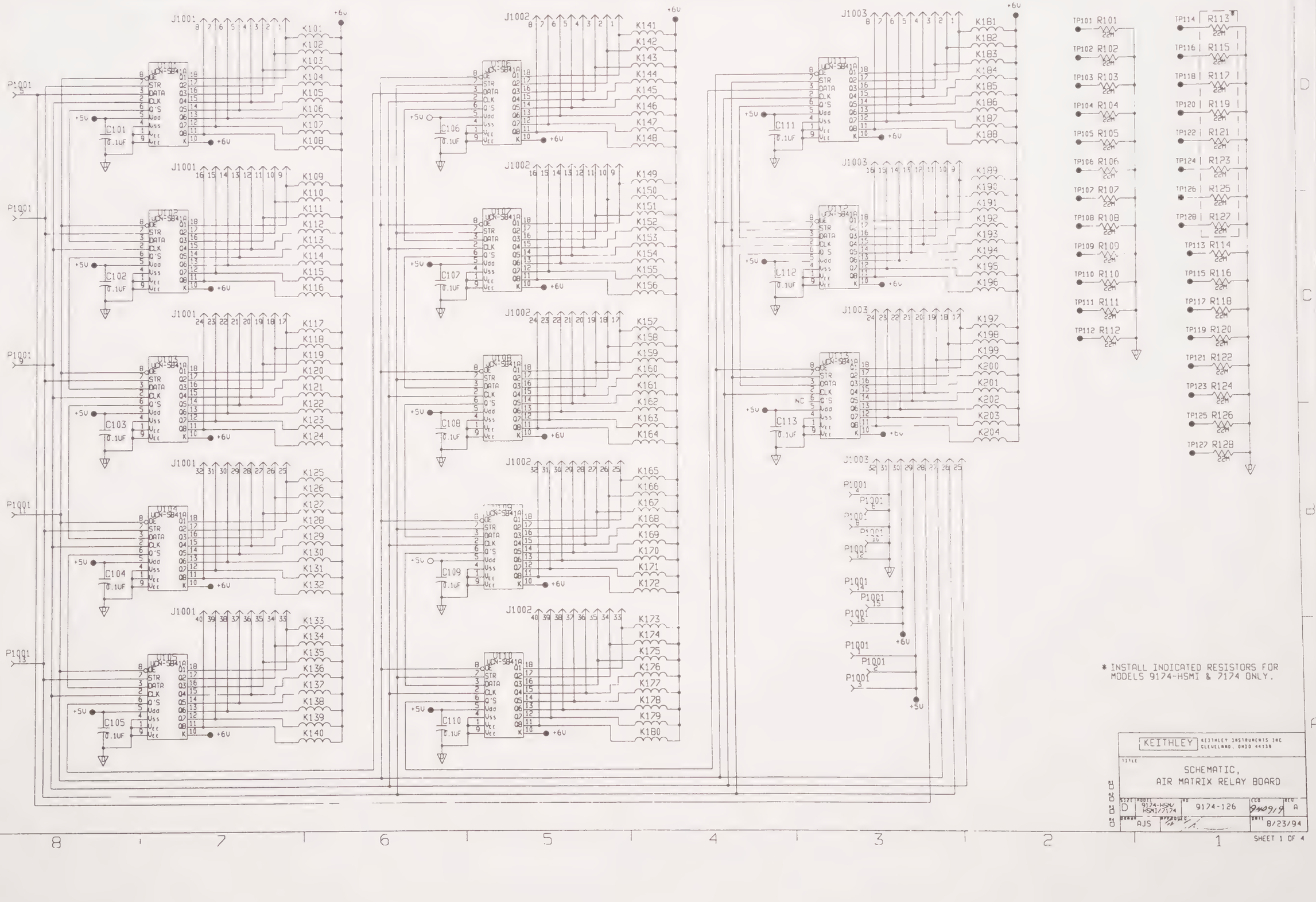
9174-122

*TP113-TP128 NOT INSTALLED

NOTE:
FOR COMPONENT INFORMATION REFER TO 9174-HSM, 9174-HSMI, AND 7174 PRODUCT STRUCTURE.

MODEL	NEXT ASSEMBLY	QTY. USED ON
7174		1
~~9174-HSMI~~		1
9174-HSM		1

DO NOT SCALE THIS DRAWING	DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 8/17/94	SCALE 1:1	TITLE COMPONENT LAYOUT, AIR MATRIX RELAY BOARD	
KEITHLEY INSTRUMENTS INC. CLEVELAND, OHIO 44139	XX=±.010 ANG.=±1°	DRN. AJS	ENG. APPR.		
	XXX=±.005 FRAC.=±1/64	MATERIAL N/A		C	NO. 9174-120
	SURFACE MAX. 63	FINISH N/A			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J1003
P1001
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+5V
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C102
C103
C104
C105
C106
C107
C108
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C110
C111
C112
C113
0.1UF
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TP123 R124
TP124 R123
TP125 R126
TP126 R125
TP127 R128
TP128 R127
22M
* INSTALL INDICATED RESISTORS FOR MODELS 9174-HSMI & 7174 ONLY.
KEITHLEY
KEITHLEY INSTRUMENTS INC
CLEVELAND, OHIO 44139
SCHEMATIC,
AIR MATRIX RELAY BOARD
SIZE D
MODEL 9174-HSMI HSMI/7174
NO 9174-126
CODE 9409/9
REV A
DRAWN AJS
DATE 8/23/94
SHEET 1 OF 4

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C
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COL#5
COL#6
COL#7
COL#8
COL#9
COL#10
COL#11
COL#12
M
S
G
FRONT
PANEL
GATEWAY INTER
CONNECT BOARD
ASS'Y 9174-160
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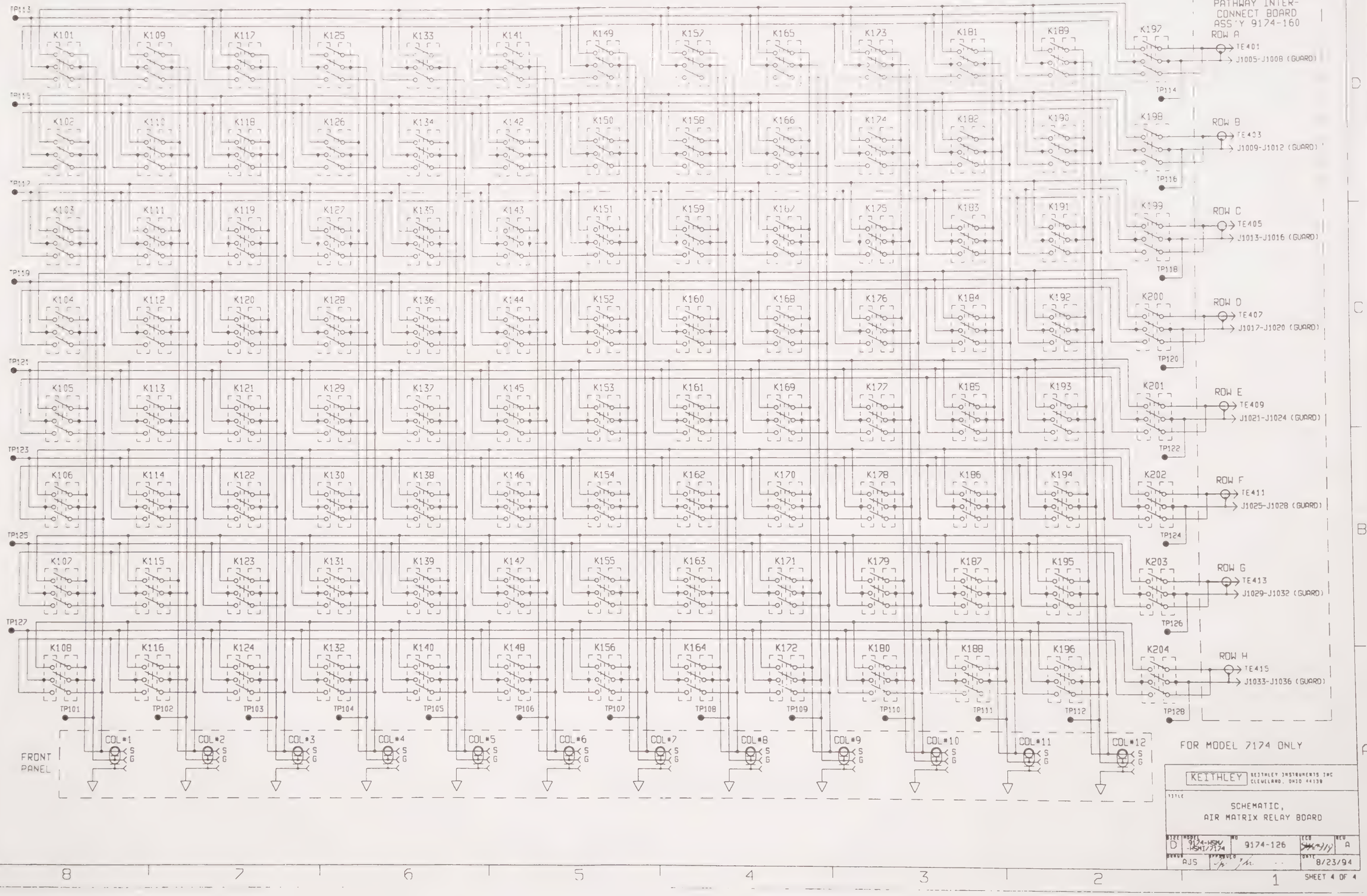
TE401
J1005-J1008 (GUARD)
TE402
ROW B
TE403
J1009-J1012 (GUARD)
TE404
ROW C
TE405
J1013-J1016 (GUARD)
TE406
ROW D
TE407
J1017-J1020 (GUARD)
TE408
ROW E
TE409
J1021-J1024 (GUARD)
TE410
ROW F
TE411
J1025-J1028 (GUARD)
TE412
ROW G
TE413
J1029-J1032 (GUARD)
TE414
ROW H
TE415
J1033-J1036 (GUARD)
TE416
FOR MODEL 9174-HSM ONLY
KEITHLEY
KEITHLEY INSTRUMENTS INC
CLEVELAND, OHIO 44139
TITLE
SCHEMATIC,
AIR MATRIX RELAY BOARD
SIZE
D
MODEL
9174-HSM
-HSM1/7174
NO
9174-126
ECO
REV
A
DRAWN
AJS
APPROVED
DATE
8/23/94
SHEET 2 OF 4

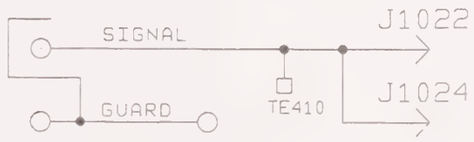
PATHWAY INTER-CONNECT BOARD ASS'Y 9174-160
ROW A
TE401
J1005-J1008 (GUARD)
TE402
ROW B
TE403
J1009-J1012 (GUARD)
TE404
ROW C
TE405
J1013-J1016 (GUARD)
TE406
ROW D
TE407
J1017-J1020 (GUARD)
TE408
ROW E
TE409
J1021-J1024 (GUARD)
TE410
ROW F
TE411
J1025-J1028 (GUARD)
TE412
ROW G
TE413
J1029-J1032 (GUARD)
TE414
ROW H
TE415
J1033-J1036 (GUARD)
TE416
FOR MODEL 9174-HSMI ONLY
FRONT PANEL
COL#1
COL#2
COL#3
COL#4
COL#5
COL#6
COL#7
COL#8
COL#9
COL#10
COL#11
KEITHLEY
KEITHLEY INSTRUMENTS INC
CLEVELAND, OHIO 44139
SCHEMATIC,
AIR MATRIX RELAY BOARD
9174-126
AJS
8/23/94
SHEET 3 OF 4

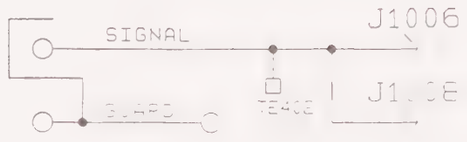

PATHWAY INTER-CONNECT BOARD ASS'Y 9174-160
ROW A
TE401
J1005-J1008 (GUARD)
ROW B
TE403
J1009-J1012 (GUARD)
ROW C
TE405
J1013-J1016 (GUARD)
ROW D
TE407
J1017-J1020 (GUARD)
ROW E
TE409
J1021-J1024 (GUARD)
ROW F
TE411
J1025-J1028 (GUARD)
ROW G
TE413
J1029-J1032 (GUARD)
ROW H
TE415
J1033-J1036 (GUARD)
FRONT PANEL
FOR MODEL 7174 ONLY
SCHEMATIC, AIR MATRIX RELAY BOARD
KEITHLEY
9174-126
AJS
8/23/94
SHEET 4 OF 4

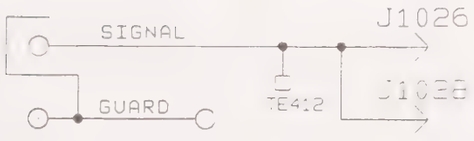
LTR.	ECO NO.	REVISION		
A	940602	RELEASED		

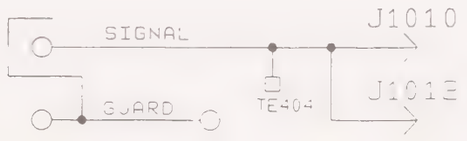
NOTE: FOR MORE COMPONENT INFORMATION REFER
TO 7174 PRODUCT STRUCTURE.

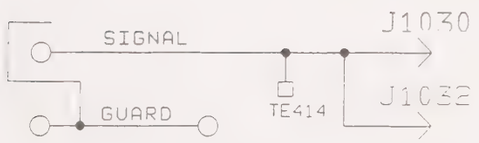
DO NOT SCALE THIS DRAWING	DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED	DATE 5/26/94	SCALE 2:1	TITLE COMPONENT LAYOUT. PATHWAY INTERCONN BD.
KEITHLEY KEITHLEY INSTRUMENTS INC. CLEVELAND OHIO 44139	XX=±.015 ANG.=±1° XXX=±.005 FRAC.=±1/64	DRN: MWH ENG: JEFF		
	SURFACE MAX. 63	MATERIAL	C	NO. 7174-160
		FINISH		

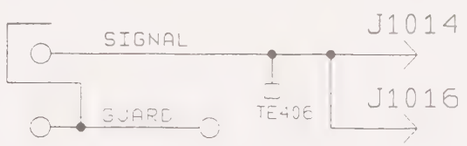


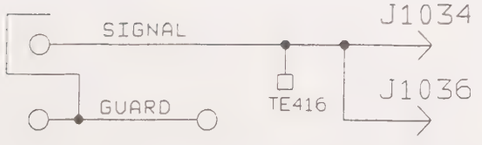


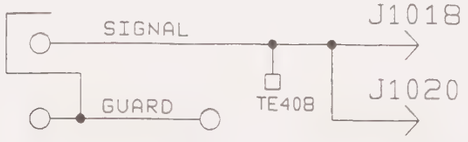












KEITHLEY — KEITHLEY INSTRUMENTS INC.
CLEVELAND, OHIO 44139

TITLE

SCHEMATIC, PATHWAY INTERCONNECT BD.

SIZE	MODEL	NO	ECO	REV
B	7174	7174-166	940602	A

DRAWN	APPROVED	DATE
MAH	W. K	5/26/94

M3 M2 M1

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Service Form

Model No. _____ **Serial No.** _____ **Date** _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

_____

_____

- ❑ Intermittent
- ❑ IEEE failure
- ❑ Front panel operational
- ❑ Analog output follows display
- ❑ Obvious problem on power-up
- ❑ All ranges or functions are bad
- ❑ Particular range or function bad; specify _____
- ❑ Batteries and fuses are OK
- ❑ Checked all cables

Display or output (check one)

- ❑ Drifts
- ❑ Unstable
- ❑ Overload
- ❑ Unable to zero
- ❑ Will not read applied input

- ❑ Calibration only
- ❑ Data required
- ❑ Certificate of calibration required

(attach any additional sheets as necessary)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)

_____

_____

What power line voltage is used? _____ Ambient temperature? _____ °F

Relative humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe.)

_____

_____

Be sure to include your name and phone number on this service form.

KEITHLEY

Keithley Instruments, Inc.
28775 Aurora Road
Cleveland, Ohio 44139

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MP MASTER
MA32989